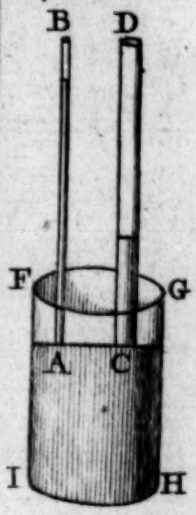
F. 17. p. 60.

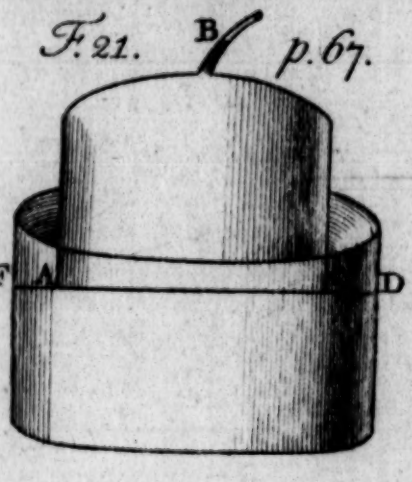


F. 18. p. 63.

F. 19. p. 64.

F. 20. p. 66.

F. 21. p. 67.



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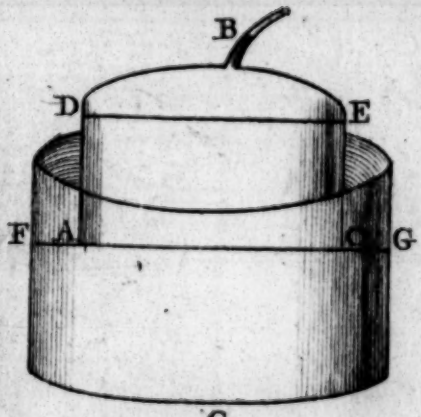

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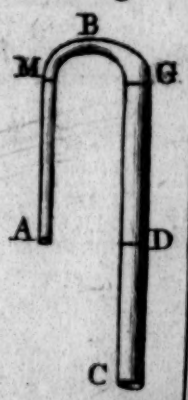
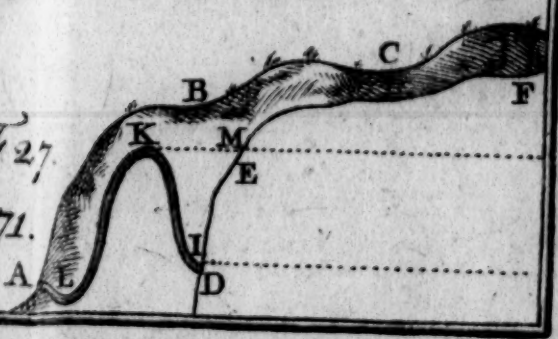


F. 26. p. 81.

F. 27. p. 71.



A

COMPENDIOUS SYSTEM OF Natural Philoſophy.

With NOTES,

Containing the MATHEMATICAL DEMONSTRATIONS, and ſome occaſional REMARKS.

PART II. Continued.

Conſiſting of five *DISSERTATIONS.*

I. Of the *Barometer.*
II. Of the Cauſe and Origin of the *Winds.*
III. Of the Aſcent of *Vapours*, and their Reſolution into *Rain*, *Hail*, *Snow*, &c.
IV. Of the Cauſes of *Thunder* and *Lightning*, with a Solution of the *Phænomena* of the *Aurora Borealis.*
V. A New Theory of *Fermentation.*

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MUSEUM

DISSERTATION IV.

Of the Barometer.

IN treating of the Properties of the Air (Chap. III.) I have already taken Notice of the Conſtruction of the common Barometer; and proved, that the Aſcent and Suſpenſion of the Mercury therein, is owing to the Preſſure * of the Air. I proceed now to a more particular Inquiry into the Original, and Uſe of this Inſtrument; and the different Forms under which it has appeared, ſince the Time of its Inventor *Torricelli*.

In

* To ſay the Aſcent and Suſpenſion of the Mercury is owing to the Preſſure and Elaſticity of the Air, as is commonly done, is inaccurate. The Variation, indeed, in the Height of the Mercury, may be aſcribed to the Elaſticity of the Air, but no otherwiſe, than as to its *remote* Cauſe; *viz.* as it occaſions an Alteration in the Quantity of Air, impending over the Place where the Variation happens; which alters its Weight, and ſo the Mercury is proportionably raiſed or depreſſed. To illuſtrate this, let it be ſuppoſed, that the Air is every where in *Æquilibrio*, quite round the Globe, and at perfect Reſt; and then, that its Elaſticity, in ſome one Place near the Surface of the Earth, is augmented by the Heat of the Sun, all the reſt of it remaining as before. The Conſequence of this will be, that the ſuperior Part of the Atmoſphere, over this Place, will be raiſed higher by the Expanſion of the inferior Air; and therefore, being unconfined, will ſpread itſelf, every way, over the neighbouring Columns, which we ſuppoſe to retain their former State. The Quantity of Matter therefore in thoſe Columns of Air, in whoſe lower Parts its Elaſticity was increaſed, will be diminiſhed, and that of the neighbouring

In the Beginning of the laſt Century it was a prevailing Opinion among Philoſophers, that the Univerſe was full of Matter; and that Nature (as they expreſſed it) abhorred a *Vacuum*: Accordingly they imagined, that if a Fluid was ſucked up a Pipe with a ſufficient Force, it would riſe to any Height whatever; ſince Nature would not ſuffer any Part of the Pipe to be empty. *Galilæo*, who flouriſhed about that Time, found upon Trial, that the common Pump would not raiſe Water, unleſs the Sucker reached within three and thirty Feet of its Surface in the Well †: From hence

ones augmented. A Barometer therefore placed in thoſe Regions, where the Air was rarified, will ſubſide; while one in the neighbouring Countries will aſcend; and they will continue at different Heights, till the denſer Air, ruſhing in upon the rarified, reſtores the *Æquilibrium*. Thus we ſee, the Variation of the Air's Elaſticity is not the *immediate* Cauſe of the Variation in the Barometer; it firſt affects the Weight of the Air, by altering the Quantity incumbent over any Place, and that affects the Barometer. But, if we may have Recourſe to *remote* Cauſes, we may, if we pleaſe, go one Step farther; and ſay, the Aſcent and Suſpenſion of the Mercury is owing to the Heat of the Sun; for by the foregoing Inſtance, a Variation in the Height of the Sun may ſometimes be the occaſion of a Variation in the Height of the Mercury.

Neither is the Suſpenſion of the Mercury, in a Tube, that is kept within Doors, to be aſcribed to the Elaſticity of the Air; for that exerts no Force, but as the internal Air is preſſed by the external, which endeavours to get in, where-ever it can find a Way.

† It is a common Notion, that a ſucking Pump will not raiſe Water above thirty-three Feet, whereas it will raiſe it to any Height whatever, if the Sucker reaches within thirty-three Feet of the Surface of the Water; as will be evident to any one that conſiders the Structure of the Pump: For all the Water, which has once

hence he judiciouſly inferred, that a Column of Water thirty-three Feet high was a Counterpoiſe to a Column of Air of an equal Baſe, whoſe Height extended to the Top of the Atmoſphere; and that, for this Reaſon, the Water would not follow the Sucker any farther. *Torricelli*, obſerving this, took the Hint; and conſidered, that, if a Column of Water, of about thirty-three Feet, was equal in Weight to a Column of Air, of the ſame Baſe §; a Co-

once paſſed through the Valve in the Sucker, is ſupported by that, as the Sucker is drawn up, and as the Sucker is let down it together with the Water between that and another placed in the Pump below, is ſupported by that other; ſo that the Height of the Water above the Sucker can be no Impediment to the riſing of the Water below the Sucker, whatever the Length of the Column, which it forms, may be. The placing one Pump above another, where Water is to be raiſed from great Depths, is rather for Strength and Conveniency, than out of Neceſſity.

§ Perhaps it may be enquired here, how it comes to paſs, that the Column of Air, which preſſes upon the ſtagnant Mercury in the Baſon, is always ſuppoſed to have an equal Baſe with the ſuſpended Column in the Tube; whereas, in Reality, its Baſe is equal to the Surface of the ſtagnant Mercury. The Reaſon is, that, as the Baſe of the Column of Air increaſes, in the ſame Proportion the Velocity, wherewith it deſcends, decreaſes, when it forces down the Surface of the Mercury in the Baſon; conſequently its Moment, or Preſſure upon the Surface of the ſtagnant Mercury (ſo far as it relates to the ſuſpending of it in the Tube) is no greater, than it would have been, had its Baſe been equal to that of the ſuſpended Column; and therefore, in conſidering it as ſuſpending a Fluid in a Tube, it is properly enough ſaid to be a Column of ſuch a Baſe.

Neither is this Suppoſition inconſiſtent with the ninth Propoſition of the firſt Chapter, where it is demonſtrated, that the Preſſure of a Fluid is in Proportion to its perpendicular Height, and the Quantity of Surface, againſt which it preſſes. For, as the Surface of the Mercury may be conſidered as a Baſe on which the

Column of Mercury, no longer than about twenty-nine Inches and a half, would be ſo too; ſuch a Column of Mercury being as heavy, as thirty-three Feet of Water. Accordingly he tried the Experiment in a Glaſs Tube (in the Manner laid down, Chap. III. § 4.) and found it to ſucceed ‡. The Apparatus he made Uſe

Column of Air reſts, ſo the Baſe of the Column of Air may be conſider'd as a Surface againſt which the Mercury preſſes. Theſe two being equal, 'tis clear, that only the Relation of the Heights of the Columns are to be conſidered, and not that of their Baſes.

‡ Notwithſtanding this clear Proof of the Preſſure of the Atmoſphere, the Aſſertors of a *Plenum* would by no Means be prevailed upon to allow it to be ſuch; but tried all Ways to account for this *Phænomenon* from ſome other Cauſe. The moſt chimerical Solution, and which at the ſame Time gave the adverſe Party the greateſt Difficulty to overthrow, was that of *Linus*. He contended, that in the upper Part of the Tube, there is a Film, or Rope of Mercury, extended thro' the ſeeming Vacuity, and that the reſt was ſuſpended by it, and kept from falling into the Baſon; and that this Film is able to ſupport about twenty-nine Inches of Mercury. He confirms his *Hypotheſis* by the following Experiment: Take, ſays he, a ſmall Tube, open at both Ends, ſuppoſe about twenty Inches long; fill this Tube with Mercury, ſtopping the lower Orifice with your Thumb: Then cloſing the upper with your Finger, and immerging the lower in ſtagnant Mercury, you ſhall perceive, upon the Removal of your Thumb, a manifeſt Suction of your Finger into the Tube; and the Tube and Mercury will both ſtick ſo cloſe to it, that you may carry them about the Room. Therefore, ſays he, the internal Cylinder of Mercury in the Tube is not held up by the preponderant Air without; for if ſo, whence comes ſo ſtrong a Suction, and ſo firm an Adheſion of the Tube to your Finger?

Or if you fill the ſame Tube almoſt full of Mercury, leaving a little Space of Air within, and then immerge it in the ſtagnant Mercury, you will find, that, notwithſtanding its Surface is at ſome Diſtance from your Finger, there will be a conſiderable Suction,

Uſe of, is now the common Barometer, or Weather Glaſs *.

The Mercury ſtanding at a leſs Height, the nearer it is carried to the Top of the Atmoſphere,

tion of it, as before. From hence he infers, that the Finger ſupports the Mercury, by Means of the abovementioned Film, and that the Preſſure of the Atmoſphere is not concerned.

But, when it was found, that the Mercury would not ſtand ſo high in the Tube, on the Top of a Mountain, as below; and would quite fall, when the circumambient Air was extracted from it by the Pump, all Objections vaniſhed; and *Linus*'s funicular *Hypotheſis* (as it was called) though it ſeemed to ſolve all other *Phænomena* relating to the Suſpenſion of the Mercury, was with Juſtice rejected.

Kircher, when this new Doctrine of a *Vacuum* was firſt advanced at *Rome*, contended, that the Authors of it were eſtabliſhing Principles not only repugnant to thoſe of Nature, but ſuch as would be prejudicial to the Orthodox Faith; as endeavouring to evince by this ſubtle Experiment, that there might be in Nature *locatum ſine loco*, *accidentia ſine ſubjecto*, and therefore made the Experiment with Water, in the following Manner. He cauſed a ſmall Bell to be fixed in the upper Part of the Tube, imagining, that, if there ſhould be a *Vacuum*, the Bell would not be made to ſound: But in making the Experiment, ſome Air got into the Tube (for he tells us, that but ten Feet of Water remained in the Tube, after it was inverted) the Bell therefore was heard to ſound; and ſo the Notion of a *Vacuum*, till more accurate Experiments evinced the contrary, was exploded with Contempt.

* *Huygens* obſerved, that, if a Tube ſeventy-five Inches long, was filled with Mercury well purged of its Air, the whole Quantity of Mercury would remain ſuſpended; whereas, according to the *Torricellian* Experiment, the Mercury ought to have ſubſided to the Height of about twenty-nine Inches.

The Cauſe of this *Phænomena* ſeems to be, that, by the great Weight of ſo long a Column of Mercury, it was preſſed into ſo cloſe Contact with the Glaſs in pouring in, that by the mutual Attraction of Coheſion between the Mercury and the Glaſs, the whole Column was ſuſtained, after the Tube was inverted.

(Chap. III. §. 7.) renders it uſeful in determining the Height of Mountains; and finding out the different Elevation of one Place above another. Accordingly, Dr *Halley* has given us a Table for that Purpoſe, in the Philoſophical Tranſactions N°. 181, ſhewing how many Feet each Inch in the Deſcent of the Mercury anſwers to, as it is conveyed to the Top of a Mountain, or other elevated Place. And Dr. *Nettleton* has done the like in the Philoſophical Tranſactions N°. 388, ſhewing what Number of Feet anſwers to each tenth Part of an Inch, from twenty-ſix to thirty-one Inches of Mercury.

But the principal Uſe of it is, to eſtimate the Gravity of the Air at different Times, in Order to foreſee the Alterations of the Weather, which are conſequent thereon. To this End, Dr. *Halley* in the ſame Tranſaction has alſo laid down the more remarkable *Phænomena*, relating to the different Heights of the Mercury at different Times, together with the Solution of each; which are ſo juſt, and ſo agreeable to true Philoſophy, that I doubt not but the Reader will excuſe me for giving his Account in his own Words, rather than to render it imperfect, by endeavouring to vary from it, or abridge it.

" 1. In calm Weather, when the Air is in-
" clined to Rain, the Mercury is commonly
" low.

" In

" 2. In ſerene, good, and ſettled Weather,
" the Mercury is generally high.

" 3. Upon very great Winds, though they
" be not accompanied with Rain, the Mercury
" ſinks loweſt of all, with Relation to the
" Point of the Compaſs the Wind blows upon.

" 4. *Cæteris paribus*, the greateſt Heights
" of the Mercury are found upon eaſterly and
" north-eaſterly Winds.

" 5. In calm froſty Weather, the Mercury
" generally ſtands high.

" 6. After very great Storms of Wind,
" when the Mercury has been low, it gene-
" rally riſes again very faſt.

" 7. The more northerly Places have greater
" Alterations of the Baromemer, than the
" more ſoutherly.

" 8. Within the Tropics, and near them,
" thoſe Accounts we have had from others,
" and my own Obſervations at St. *Helena*,
" make very little or no Variation of the
" Height of the Mercury in all Weathers.

" Hence I conceive that the principal Cauſe
" of the Riſe and Fall of the Mercury, is from
" the variable Winds, which are found in the
" temperate Zone, and whoſe great Uncon-
" ſtancy, here in *England*, is moſt notorious.

" A ſecond Cauſe is the uncertain Exhalation
" and Precipitation of the Vapours lodging in
" the Air, whereby it comes to be at one Time,
" much more crouded than at another, and

" con-

" conſequently heavier, but this latter in a great
" Meaſure depends upon the former. Now,
" from theſe Principles, I ſhall endeavour to
" explicate the ſeveral *Phænomena* of the Ba-
" rometer, taking them in the ſame Order I
" laid them down, Thus,

" 1. The Mercury's being low, inclines it
" to rain, becauſe the Air being light, the
" Vapours are no longer ſupported thereby,
" being become ſpecifically heavier than the
" Medium wherein they floated, ſo that they
" deſcend towards the Earth, and in their Fall,
" meeting with other aqueous Particles, they
" incorporate together, and form little Drops
" of Rain; but the Mercury's being at one
" Time lower than at another, is the Effect of
" two contrary Winds blowing from the Place
" where the Barometer ſtands; whereby the
" Air of that Place is carried both Ways from
" it, and, conſequently, the incumbent Cylin-
" der of Air is diminiſhed, and accordingly the
" Mercury ſinks: As for Inſtance, if in the
" *German* Ocean it ſhould blow a Gale of
" weſterly Wind, and at the ſame Time an
" eaſterly Wind in the *Iriſh* Sea; or if in
" *France* it ſhould blow a northerly Wind,
" and in *Scotland* a ſoutherly; it muſt be
" granted, that that Part of the Atmoſphere
" impendant over *England*, would thereby be
" exhauſted and attenuated, and the Mercury
" would ſubſide, and the Vapours, which be-

" fore

" fore floated in thoſe Parts of the Air of
" equal Gravity with themſelves, would ſink
" to the Earth.

" 2. The greater Height of the Barometer
" is occaſioned by two contrary Winds blow-
" ing towards the Place of Obſervation, where-
" by the Air of other Places is brought thither
" and accumulated; ſo that the incumbent
" Cylinder of Air, being encreaſed both in
" Height and Weight, the Mercury preſſed
" thereby muſt needs ſtand high, as long as
" the Winds continue ſo to blow; and then
" the Air being ſpecifically heavier, the Va-
" pours are better kept ſuſpended, ſo that they
" have no Inclination to precipitate and fall
" down in Drops, which is the Reaſon of the
" ſerene good Weather which attends the
" greater Heights of the Mercury.

" 3. The Mercury ſinks the loweſt of all by
" the very rapid Motion of the Air in Storms
" of Wind. For the Tract or Region of the
" Earth's Surface, wherein the Winds rage,
" not extending all round the Globe, that
" ſtagnant Air which is left behind, as like-
" wiſe that on the Sides, cannot come in ſo
" faſt as to ſupply the Evacuation made by ſo
" ſwift a Current, ſo that the Air muſt neceſ-
" ſarily be attenuated, when and where the
" ſaid Winds continue to blow, and that more
" or leſs, according to their Violence: add
" to which, that the horizontal Motion of the

" Air being ſo quick as it is, may, in all Pro-
" bability, take off ſome Part of the perpendi-
" cular Preſſure thereof; and the great Agi-
" tation of its Particles is the Reaſon why the
" Vapours are diſſipated, and do not condenſe
" into Drops, ſo as to form Rain, otherwiſe
" the natural Conſequence of the Air's Rare-
" faction †.

" 4. The Mercury ſtands the higheſt upon
" the eaſterly and north-eaſterly Wind, be-
" cauſe in the great *Atlantic* Ocean, on this
" Side the thirty-fifth Degree of north Lati-
" tude, the Winds are almoſt always weſter-
" ly or ſouth-weſterly; ſo that whenever
" here the Winds come up at eaſt and north-
" eaſt, 'tis ſure to be checked by a contrary
" Gale as ſoon as it reaches the Ocean; where-
" fore, according to what is made out in our
" ſecond Remark, the Air muſt needs be heap-

† The Reaſon the Doctor aſſigns for the ſinking of the Mercury the loweſt of all in violent ſtorms of Wind, ſeems not ſufficient. Perhaps it may be better accounted for thus; the Cauſe why the Wind blows at all, is in order to reſtore the *Æquilibrium* of the Atmoſphere, when loſt (as may be inferred from what was ſaid in the firſt Note of this, and will be more largely explained in the following Diſſertation;) it therefore always blows towards that Point, where the Air is moſt rarefied and lighteſt. Now the Air in its Progreſs to that Point, muſt certainly move faſter and faſter; for the Cauſe which gave it Motion at firſt, continues to to act upon it all the Way. Conſequently, in whatever Place the Wind blows with great Rapidity, that Place is at, or near the Point, where the Air is moſt rarefied, and lighteſt; which is a ſufficient Reaſon for the Mercury's ſtanding low at that Place.

" ed

" ed over this Iſland, and conſequently the " Mercury muſt ſtand high, as often as theſe " Winds blow. This holds true in this Coun- " try, but is not a general Rule for others, " where the Winds are under different Cir- " cumſtances ; and I have ſometimes ſeen the " Mercury here, as low as twenty-nine Inches " upon an eaſterly Wind, but then it blew ex- " ceeding hard, and ſo comes to be accounted " for, by what was obſerved upon the third " Remark.

" 5. In calm froſty Weather the Mercury " generall ſtands high, becauſe (as I con- " ceive) it ſeldom freezes, but when the Winds " come out of the northern, and north-eaſtern " Quarters ; or, at leaſt, unleſs thoſe Winds " blow at no great Diſtance off : For the " north Parts of *Germany*, *Denmark*, *Swe-* " *den*, *Norway*, and all that Tract from " whence north-eaſtern Winds come, are " ſubject to almoſt continual Froſt all the " Winter ; and thereby the lower Air is very " much condenſed, and in that State is brought " hitherwards by thoſe Winds, and being ac- " cumulated by the Oppoſition of the weſter- " ly Wind blowing in the *Ocean*, the Mer- " cury muſt needs be preſſed to a more than " ordinary Height ; and, as a concurring " Cauſe, the ſhrinking of the lower Parts of " the Air into leſſer Room by Cold, muſt

" needs cauſe a Deſcent of the upper Parts of " the Atmoſphere, to reduce the Cavity made " by this Contraction to an *Æquilibrium*.

" 6. After great Storms, when the Mer- " cury has been very low, it generally riſes " again very faſt: I once obſerved it to riſe " one Inch and a half in leſs than ſix Hours, " after a long continued Storm of ſouth-weſt " Wind. The Reaſon is, becauſe the Air be- " ing very much rarefied, by the great Eva- " cuations which ſuch continued Storms make " thereof, the neighbouring Air runs in the " more ſwiftly, to bring it to an *Æquilibri-* " *um*; as we ſee Water runs the faſter for " having a greater Declivity.

" 7. The Variations are greater in the more " northerly Places, as at *Stockholm*, greater " than that at *Paris* (compar'd by M. *Paſ-* " *chal*;) becauſe the more northerly Parts " have uſually greater Storms of Wind than " the more ſoutherly, whereby the Mercury " ſhould ſink lower in that Extream; and " then the northerly Winds bringing the more " denſe and ponderous Air from the Neigh- " bourhood of the Pole, and that again being " checked by a ſoutherly Wind at no great " Diſtance, and ſo heaped, muſt of Neceſſity " make the Mercury in ſuch Caſe ſtand higher " in the other Extream.

" 8. Laſtly,

"8. Laſtly, this Remark, That there is "little or no Variation near the *Equinoctial*, "does above all others confirm the *Hypothe-* "*ſis* of the variable Winds being the Cauſe of "theſe Variations of the Height of the Mer- "cury; for in the Places above-named, there "is always an eaſy Gale of Wind blowing "nearly upon the ſame Point, *viz.* eaſt-north- "eaſt, at *Barbadoes*, and eaſt-ſouth-eaſt at "St. *Helena* *, ſo that there being no contra- "ry Currents of Air to exhauſt or accumulate "it, the Atmoſphere continues much in the "ſame State: However, upon Hurricanes "(the moſt violent of Storms) the Mercury "has been obſerved very low, but this is but "once in two or three Years, and it ſoon re- "covers its ſettled State about 29 ½ Inches."

Monſieur *Leibnitz* accounted for the Deſcent of the Mercury before Rain, upon another Principle †, *viz.* as a Body ſpecifically lighter than a Fluid, while it is ſuſpended by it, adds more Weight to that Fluid, than when, by being reduced in its Bulk, it becomes ſpecifically heavier, and deſcends; ſo the Vapour, after it is reduced into the Form of Clouds, and deſcends, adds leſs Weight to the Air, than before; and therefore the Mer-

* See the Cauſe of this aſſigned in the following Diſſertation.

† Memoir. de l'Acad. 1711.

cury

cury falls. To which it is anſwered, 1*ſt*. That when a Body deſcends in a Fluid, its Motion, in a very little Time, becomes uniform, (or nearly ſo) a farther Acceleration of it being prevented by the Reſiſtance of the Fluid; and then, by the third Law of Nature, it preſſes the Fluid downwards, with a Force equal to that whereby it tends to be farther accelerated, that is, with a Force equal to its whole Weight. 2*dly*. The Mercury, by its Deſcent, foretells Rain a much longer Time before it comes, than the Vapour, after it is condenſed into Clouds, can be ſuppoſed to take up in falling. 3*dly*. Suppoſing that as many Vapours, as fall in Rain, during the Space of a whole Year, where at once to be condenſed into Clouds, and even quite ceaſe to gravitate upon the Air, its Gravity would ſcarce be diminiſhed thereby, ſo much as is equivalent to the Deſcent of two Inches of Mercury in the Barometer. Farther, in many Places between the Tropics, the Rains fall at certain Seaſons, in very great Quantities *, and yet the Barometer ſhews there very little or no Alteration in the Weight of the Air.

The following are Mr. *Patrick*'s Obſervations on the riſing and falling of the Mercury. They are very juſt, and are to be accounted

* See Diſſertation the VI.

for

for on the ſame Principles with thoſe of Dr. *Halley*.

" 1. The riſing of the Mercury preſages in " general fair Weather; and its falling, foul " Weather; as Rain, Snow, high Winds and " Storms.

" 2. In very hot Weather, the falling of " the Mercury foreſhews Thunder.

" 3. In Winter the riſing preſages Froſt; " and in froſty Weather, if the Mercury falls " three or four Diviſions, there will *certain-* " *ly* follow a Thaw. But in a continued " Froſt, if the Mercury riſes, it will *certain-* " *ly* ſnow.

" 4. When foul Weather happens ſoon after " the Falling of the Mercury, expect but little " of it. And, on the contrary, expect but " little fair Weather, when it proves fair " ſhortly after the Mercury has riſen.

" 5. In foul Weather, when the Mercury " riſes much and high, and ſo continues for " two or three Days before the foul Weather " is quite over, then expect a Continuance of " fair Weather to follow.

" 6. In fair Weather, when the Mercury " falls much and low, and thus continues for " two or three Days before the Rain comes; " then expect a great deal of wet, and pro- " bably high Winds.

" 7 The

" 7. The unſettled Motion of the Mercury " denotes uncertain and changeable Weather.

" 8. You are not ſo ſtrictly to obſerve the " Words engraved on the Plates (though, for " the moſt Part, it will agree with them) as " the Mercury's *Riſing* and *Falling*: For if " it ſtands at *Much Rain*, and then riſes up " to *Changeable*, it preſages fair Weather, al- " though not to continue ſo long, as it would " have done, if the Mercury were higher: " And ſo on the contrary, if the Mercury " ſtood at *Fair*, and falls to *Changeable*, it " preſages foul Weather; though not ſo much " of it, as if it had ſunk down lower."

From theſe Obſervations, it appears, That it is not ſo much the Height of the Mercury in the Tube, that indicates the Weather, as the Motion of it up and down; wherefore in Order to paſs a right Judgment of what Weather is to be expected, we ought to know, whether the Mercury is actually *Riſing* or *Falling*, to which End, the following Ruls are of Uſe.

1, If the Surface of the Mercury is convex, ſtanding higher in the Middle of the Tube than at the Sides, it is generally a Sign that the Mercury is then riſing.

2. If the Surface is concave, or hollow in the Middle, it is ſinking And,

3, If

3. If it is plain, the Mercury is ſtationary, or rather, if it is a little convex; for Mercury being put into a Glaſs Tube, eſpecially a ſmall one, will naturally have its Surface a little convex; becauſe the Particles of Mercury attract each other more forcibly than they are attracted by Glaſs. Further,

4. If the Glaſs is ſmall, ſhake the Tube; and if the Air is grown heavier, the Mercury will riſe about half the tenth of an Inch higher, than it ſtood before; if it is growing lighter, it will ſink as much. This proceeds from the Mercury's ſticking to the Sides of the Tube, which prevents the free Motion of it, till it is diſengaged by the Shock. And therefore, when an Obſervation is to be made with ſuch a Tube, it ought always to be ſhaken firſt, for ſometimes the Mercury will not vary of its own Accord, till the Weather, it ought to have indicated, is preſent.

The Uſefulneſs of knowing, whether the Mercury is actually riſing or falling; and the Advantage that would ariſe from perceiving the moſt minute Variations in eſtimating the Heights of Places, have given Occaſion to the Invention of ſeveral Kinds of Barometers different from the *Torricellian*, though founded on the ſame Principle; wherein the Scale of Variation, which in that is not above three Inches,

ſhould be conſiderably larger. Of which I am now to give ſome Account.

1. The firſt is that of *Des Cartes*, which was made in the Form expreſſed, *Fig.* 28. where AB is a Tube hermetically * ſealed at A, and having its lower Orifice immerged in ſtagnant Mercury E F, and filled with the ſame Fluid to G, from thence to H with Water, and empty from thence to the Top. Now when the Mercury riſes in this Tube, ſuppoſe from G to L, the Water will be raiſed in the ſmall Tube, perhaps from H to M, *viz.* as many Times further, as the Tube CA is ſmaller than CD; by which Means the Variations become much more ſenſible, than they are in the common Barometer. The Inconvenience of this was, that the Air, included in the Water, getting looſe by Degrees, filled the void Space at the Top, and ſo ſpoiled the Machine.

2. He then contrived it thus, ABC (*Fig.* 29.) is a bent Tube hermetically ſealed at A, filled with Water from F to D (tinged with *Aqua Regia* to prevent its freezing) from D to E with Mercury, and empty from thence to the Top. Then, upon the Mercury's riſing, ſuppoſe from

* A Tube is ſaid to be *hermetically* ſealed, when the End is ſo cloſed, that nothing can poſſibly evaporate through it. And, becauſe this is beſt done, when it is cloſed up with its own Subſtance; or when its Bore does not reach quite to the End of it, it is then ſaid to be *hermetically* ſealed.

E to

E to M, and falling as much at D, the Surface of the Water at F would ſink ſo many Times farther than the Surface of the Mercury at D, as the Tube CG was ſmaller than GH. The Water here is liable to evaporate, though that may, in ſome Meaſure, be prevented, by pouring a few Drops of Oil of ſweet Almonds upon it. Others have contrived

3. The Horizontal or Rectangular Barometer (Fig. 30.) hermetically ſealed at A, and filled with Mercury from D to E; then as the upper Surface of it riſes in the Tube, ſuppoſe from E to F, the lower will be driven from D to G, as many Times farther, as this Part of the Tube is leſs than that at E. But it often happens, that ſome Parts of the Mercury break off from the reſt in the Leg BC, and are left behind. This Inconvenience is remedied in

4. The Diagonal Barometer ABC (*Fig.* 31.) wherein the Mercury, inſtead of riſing from B to D (ſuppoſe that Space to correſpond to the Scale of Variation in a ſtrait Tube) will riſe from B to A; for it will always ſtand at the ſame perpendicular Height, whatever be the Inclination of the Tube; becauſe Fluids preſs only according to their perpendicular Altitude *. But the Tube AB muſt not be too much inclined, leſt the Mercury break in it, as in the former.

* Chapter I. §. 9.

5. AB (*Fig.* 32.) is Dr. *Rook's* Wheel-Barometer, wherein ABD is a Tube filled with Mercury from *a* to E; *a* is an Iron Ball, ſwimming on the Surface of the Mercury; this as it ſubſides with the Surface of the Mercury, draws the little Wheel *m n* round, to whoſe Circumference it is fixed by Means of the String *a c* *: This Wheel carries the Index P Q, which points to the graduated Edge of the Circle KL, and by its Motion ſhews the moſt minute Variations of the Mercury. When the Ball *a* is raiſed by the Mercury on which it ſwims, the Index is drawn the contrary Way by a leſſer Ball *b*, which hangs on the other Side the Wheel. The Friction in this Machine, unleſs it be made with great Accuracy indeed, renders it uſeleſs.

6. The pendent Barometer is another Contrivance to render the Variations more ſenſible. It conſiſts of a ſmall conical Tube, (repreſented *Fig.* 33.) hermetically ſealed at A, and filled with Mercury from C to D, and empty from thence to A. Now, ſuppoſing the Gravity of the Air encreaſed, it will raiſe the Mercury higher in the Tube, and ſo force it into a narrower Part; by which Means the Column becoming longer, its perpendicular Preſſure upon the Air below will be proportionably encreaſed.

* The Tube is ſmaller at *a* than at F, that the greateſt Variation may be at that Surface of the Mercury on which the Ball reſts.

On

On the contrary, when the Air becomes lighter, the Mercury deſcends into a larger Part of the Tube, and by that Means has the Length of its Column proportionably contracted. The Inconvenience that attends this Barometer, is that the Tube muſt be very ſmall, otherwiſe the Mercury will fall out; or the Air will be apt to get into it, and divide the Column in ſeveral Places; and when the Tube is very ſmall, the Friction of the Mercury againſt the Sides of it, will hinder it from riſing and falling freely.

7. Dr. *Hook*, obſerving how unfit the common Barometer, was to be uſed on Board of Ship, by Reaſon its Poſition ought to be ſteady, contrived the following one, called, from its Uſe, a *Marine* Barometer, conſiſting of two Parts, the one A B (*Fig.* 34.) the common Spirit Thermometer, the other CD, a Tube filled with Air from C to E, and from thence to the End D with tinged Water. This End is immerged in the ſame Fluid contained in the Veſſel G F; and having its Surface expoſed to the Preſſure of the external Air. Now, the laſt of theſe Machines will be affected both by the Warmth of the external Air, and alſo by its Preſſure: The former dilating the Air included in CE, and by that Means driving the Water downwards; the latter preſſing it up higher in the Tube: Whereas the other, *viz.* AB, is affected by the Warmth of the Air alone. Conſequently,

ſequently, were theſe Inſtruments graduated in ſuch a Manner, that, if the Gravity of the external Air ſhould always remain the ſame it was, when the Inſtruments were made, their Variations (then only depending on its Warmth) ſhould exactly correſpond with each other; that is, when the Spirit in the Tube A B, ſhould aſcend to 1, the Water in C D, ſhould deſcend to 1, *&c.* Then, whenever their Variations ſhould be obſerved to differ from each other, the Difference could only be aſcribed to ſome Alteration in the Preſſure of the Air upon the Surface of the Water in the Veſſel G F. In Proportion therefore as the Difference is greater, or leſs, ſo is the Alteration in the Gravity of the Air, from what it was when the Inſtruments were adjuſted. For Inſtance, when the Water ſtands above the Diviſion, which correſponds to that, which the Spirit points to in the other Machine, it is an Indication, that the Preſſure of the Air is greater at that Time, than when the Inſtruments were graduated, and *vice verſâ*.

This Machine is not only more uſeful at Sea, than the common one, as not requiring a ſteady Poſition; but may have its Scale of Variation conſiderably enlarged, by making the Bore of the Tube C D very ſmall, in Proportion to the Capacity of its Head C.

But

But it is obſerved, that in long keeping the Inſtrument, the included Air loſes ſomewhat of its Elaſticity; whereby, in Proceſs of Time, the Water ſtands higher than it ought, and therefore indicates the Gravity of the Air to be greater than what it is.

In the Philoſophical Tranſactions N°. 427. I have given an Account of a Barometer, wherein the Scale of Variation may be encreaſed *ad Infinitum*. The Deſcription of it is as follows: A B C D (*Fig.* 35.) is a cylindrical Veſſel, filled with a Fluid to the Height W, in which is immerged the Barometer S V, conſiſting of the following Parts: The Principal of which is a Glaſs Tube, T P (repreſented ſeparately at *t p*) whoſe upper End T is hermetically ſealed: This End does not appear to the Eye, being received into the lower End of a Tin Pipe G H, which in its other End G receives a cylindrical Rod, or Tube S T, and thereby fixes it to the Tube TP. This Rod ST may be taken off, in Order to put in its ſtead a larger, or leſſer, as Occaſion requires. S is a Star at the Top of the Rod ST, and ſerves as an Index, by pointing to the graduated Scale L A, which is fixed to the Cover of the Veſſel A B C D. M N is a large cylindrical Tube made of Tin (repreſented ſeparately at *m n*) which receives in its Cavity the ſmaller Part of the Tube TP, and is well cemented to it

at

at both Ends, that none of the Fluid may get in.

The Tube TP, with this Apparatus, being filled with Mercury, and plunged into the Baſon V, which hangs by two, or more Wires, upon the lower End of the Tube MN, muſt be ſo poized, as to float in the Liquor contained in the Veſſel A B C D, and then the whole Machine will riſe, when the Atmoſphere becomes lighter, and *vice verſâ*.

I ſhall hereadd a Computation, in Order to ſhew the Poſſibility of the Variation being infinite, upon a given finite Variation of the Weight of the Atmoſphere, and withal, the Reaſon why it may be ſo. Thoſe who would ſee a Mathematical Proof of it, may conſult the Note below. *

Let

* Let the ſpecific Gravity of Quickſilver be to that of Water, or to the Liquor the Barometer floats in, as i to 1; and if it be propoſed, that the Variations in this compound Barometer ſhall be to the contemporary Variations of the common Barometer in the given Ratio of n to 1, this Effect will be obtained, by making the Diameter of the Rod ST to the Diameter of the Cavity of the Tube HI, as $\sqrt{\frac{n+s}{ns}}$ to 1, which may be thus demonſtrated.

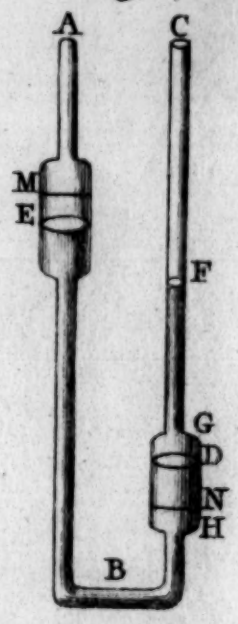
Let us ſuppoſe, that the Variation in the Height of the Quickſilver in the common Barometer, which we will call v, is ſuch, that a cubic Inch of Quickſilver ſhall riſe into the *Vacuum* XT; in Order to which, a cubic Inch of Quickſilver muſt riſe from the Veſſel V; that is, the Surface P muſt ſubſide ſo far, that a cubic Inch of Water (if that be the Fluid made Uſe of) ſhall enter the Veſſel V, by which Means the Barometer with the Parts annexed will be heavier by a cubic Inch of the Fluid.

Now

Part II. Plate V. p. 106.

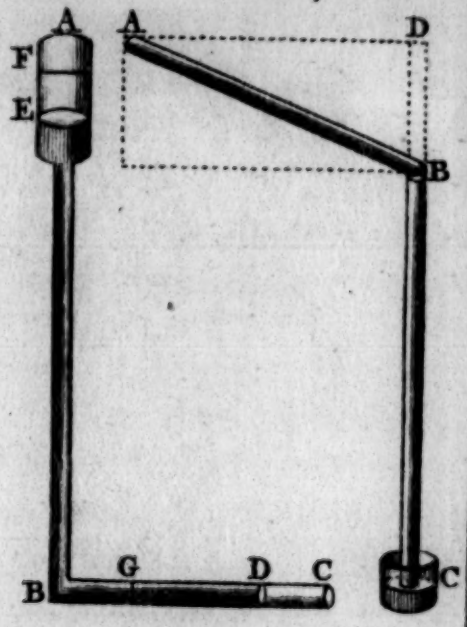
F. 28.

F. 29. p. 100.

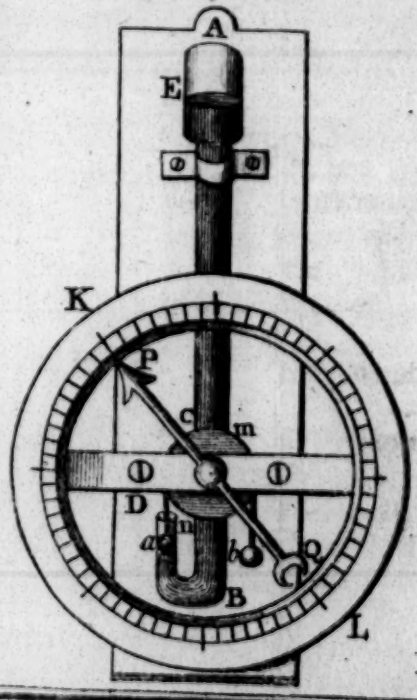


F. 30.

F. 31. p. 101.

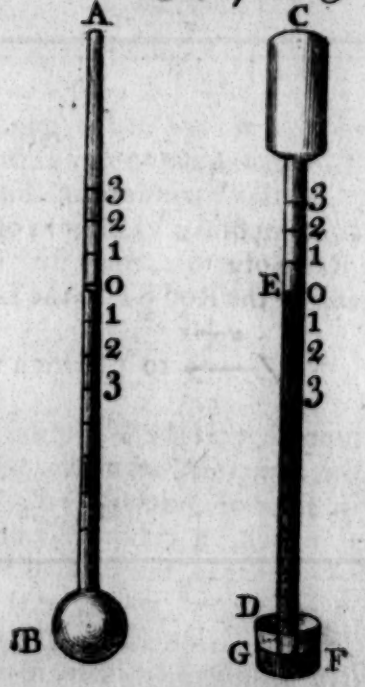


F. 32. p. 102.



F. 33.

F. 34. p. 103.



Let it be ſuppoſed, that the Fluid made uſe of is Water, and that the given Variation in the Weight of the Atmoſphere is ſuch, that, by

Now this additional Weight of a cubic Inch of Fluid, will make the whole Barometer ſubſide (according to the Law of Hydroſtatics) till a cubic Inch of the Rod HS, immediately extant above the Surface at W, ſhall come under it; but the Length of ſuch a Magnitude of HS will exceed the Length of an equal Magnitude of Quickſilver in the larger Tube X, as many Times as the Square of the Diameter at X exceeds the Square of the Diameter at H (the Lengths of equal Cylinders being reciprocal to their Baſes.) That is, the perpendicular Deſcent of the compound Barometer will be to v; the perpendicular Aſcent of the Mercury in the common Barometer, as d to 1 (ſuppoſing this the Ratio of their Baſes, and conſequently will be equal to dv.

But, by this Deſcent, the Diſtance PW, between the Surface of the ſtagnant Quickſilver and the Top of the Fluid, will be augmented by a Column, whoſe Height is dv, the Deſcent of the compound Barometer; and conſequently the Weight of the whole Column of the Fluid preſſing on the lower Surface of the Quickſilver (to which the Height X is partly owing) will be encreaſed by a Column of that Length; and this Increaſe would produce a ſecond Aſcent of the Mercury at X equal to itſelf, namely, dv, were the Fluid as heavy as Quickſilver; but ſince it is ſuppoſed to be lighter in the Ratio of s to 1, the Aſcent of the Quickſilver, on this Account, will only be $\frac{dv}{s}$.

But now, as in the former Caſe, when the Aſcent of the Mercury was v, the Deſcent of the compound Barometer was ſhewn to be dv; ſo here, the Aſcent of the Mercury being $\frac{dv}{s}$ the Deſcent of the compound Barometer will be $\frac{ddv}{s}$ and the next Deſcent $\frac{dddv}{ss}$ and the next $\frac{d^4v}{s^3}$ and ſo on to Infinity. Therefore the whole Deſcent of the compound Barometer, is to the Aſcent of the Mercury in the common Barometer, that is, n is to 1 as $d + \frac{dd}{s} + \frac{ddd}{ss} + \frac{d^4}{s^3} + \&c.$ to 1, or as $\frac{ds}{s-d}$ to 1; because the Terms of the Series being in geometrical Proportion,

by preſſing upon the Surface of it at W, the Surface of the Mercury at X may be raiſed an Inch higher (meaſuring from its Surface at P) than before; and that the Breadth of the Cavity of the Tube at X, and of the Baſon at P are ſuch, that by this Aſcent of the Mercury, there may be a cubic Inch of it in the Cavity X more than before, and conſequently in the Baſon a cubic Inch leſs. Now upon this Suppoſition, there will be a cubic Inch of Water in the Baſon more than there was before; becauſe the Water will ſucceed the Mercury to fill up its Place. Upon this Account the whole Machine will be render'd heavier than it was before, by the Weight of a cubic Inch of Water, and therefore will ſink, according to the Laws of Hydroſtatics (Chap. II. §. 5.) till a cubic Inch of that Part of the Rod WS, which

the Sum of them all is $\frac{ds}{s-d}$. Hence we have $n = \frac{ds}{s-d}$, and therefore $ns = ds + dn$; that is, $1 : d :: n+s : ns :: \frac{n+s}{ns} : 1$; and therefore, by extracting the ſquare Roots of each Term in the Proportion, $1 : \sqrt{d}$ (that is, the Diameter of ST to the Diameter of HI) as $\sqrt{\frac{n+s}{ns}}$ to 1. *Q. E. D.*

Example 1. Putting $s = 14$ and $n = 1$, the Variation in each Barometer will be equal, by taking the Diameter of ST to the Diameter of HI, as $\sqrt{\frac{15}{14}}$ to 1, that is, as 30 to 29 nearly.

Example 2. If n be put infinite, the Diameter of ST will be to the Diameter of HI, as $\sqrt{\frac{1}{s}}$ to 1, or 1 to $\sqrt{14}$; that is, as 1 to $3\frac{3}{4}$ nearly.

was

was above the Surface of the Water at W, comes under it. Then, if we ſuppoſe this Rod ſo ſmall, that a cubic Inch of it ſhall be fourteen Inches in Length, the whole Machine will ſink fourteen Inches lower into the Fluid than before, and conſequently the Surface of the Mercury in the Baſon will be preſſed more than it was before, by a Column of Water fourteen Inches high. But the Preſſure of fourteen Inches of Water is equivalent to one of Mercury (becauſe Water is about fourteen Times lighter than Mercury) this additional Preſſure therefore will make the Mercury aſcend at X, as much as the ſuppoſed Variation in the Weight of the Air did at firſt. This Aſcent will give Room for a ſecond cubic Inch of Water to enter the Baſon; the Machine will therefore be again rendered heavier by the Weight of ſo much Water, and accordingly will ſubſide fourteen Inches farther. This will occaſion another additional Preſſure of Water, which will raiſe another Inch of Mercury, and make the Machine ſink fourteen Inches more, and ſo on, without ever approaching nearer to an *Æquilibrium* with the external Air: And therefore a Scale, anſwering to the Variation of this Barometer, ought ſtrictly and properly to be of an infinite Length; becauſe after this Barometer has ſunk or riſen thouſands of Miles (if that were poſſible) it would ſtill have the ſame Tendency to ſink or riſe on, as when it firſt ſet out.

Now, was the Rod WS ſmall, that a cubic Inch of it ſhould be more than fourteen Inches long (the other Parts remaining as was ſuppoſed above) the Variation in this Barometer would be more than infinite, or negative with Reſpect to thoſe of the common Barometer. The Meaning of which is, that whereas in the common Barometer, the ſuſpended Column of Mercury, by its riſing or falling, approaches nearer to an *Æquilibrium* with the external Air. this Barometer would continually recede from an *Æquilibrium* with it; ſo that the farther it ſhould move up or down, inſtead of acquiring by that Means a leſs Tendency to move on, as the Mercury in the common Barometer does, it would acquire a greater.

On the contrary, when a cubic Inch of the Rod is leſs than fourteen Inches in Length, the Variation will be finite; and may be made to bear any Proportion to thoſe of the common Barometer whatever, as demonſtrated in the foregoing Note.

While I am writing this, another Method occurs to me of making a Barometer, wherein the Scale of Variation ſhall bear any Proportion to that of the common one. It is this: Let there be a compound Tube, as ABC (*Fig.* 36,) hermetically ſealed at A, and open at C, empty from A to D, filled with Mercury from thence to B, and from thence to E with Water;

ter: Then, if the Tube FC be a little more than five Times leſs in Diameter than the Tube FA, the Variation in the lower Surface of the Water et E will be infinite; if it be above ſo many Times leſs, it will be more than infinite, otherwiſe it will be finite. See the Demonſtration in the Note *.

That

* Let v denote a given Variation in the common Barometer, x the correſpondent Variation at E ſought. Let the Ratio of m to 1, expreſs that of the ſpecific Gravity of Mercury, to that of Water; and d to 1, that of the Diameter of the Tube FA to FC. Then the Variation at E, the lower Surface of the Water, being ſuppoſed x, the Variation of it at B, the upper Surface of it will be $\frac{x}{dd}$, and conſequently GE, the Difference of the Legs EK and KB, will vary $x + \frac{x}{dd}$. Again, the Variation of the Surface of the Mercury at B will be the ſame with that of the Water in the ſame Place, *viz*, $\frac{x}{dd}$; and, if the Tube is of the ſame Diameter at D, as at B, the Variation of the Surface at D will alſo be the ſame, that is, $\frac{x}{dd}$: The Sum of both Variations, or the Variation of HD the Difference of the Legs, will therefore be $\frac{2x}{dd}$. Now the Preſſure of the Mercury and Water together upon the Air at E, is owing to the Lengths of HD and GE; and ſince one of theſe will always ſhorten, when the other lengthens, the Variation in their Preſſure will depend on the Variation of the Difference of their Weights, that is, of the Difference between the Weight of $x + \frac{x}{dd}$ and of $\frac{2x}{dd}$. But the Weight of $x + \frac{x}{dd}$ (being the Weight of a Column of Water) compared to that of a Column of Mercury of the ſame Length, is only $\frac{x + \frac{x}{dd}}{m}$. The Difference therefore between

That the Variation in this Barometer may be infinite, will appear from the following Computation.

Let the Proportion between the Bores of the Tube AF and FC be ſuch, that when HD, the Difference of the Legs wherein the Mercury is contained, is augmented one Inch, GE the Difference of the Legs, wherein the Water is contained, ſhall be diminiſhed fourteen; then, as much as the Preſſure of the Mercury is augmented, that of the Water will be diminiſhed, and ſo the Preſſure of both taken together will remain as it was. And conſequently, after it has began to riſe, it will always have the ſame Tendency to riſe on, without ever coming to an *Æquilibrium* with the Air.

How far this Barometer will ſucceed in Practice, muſt be left to Experience to determine.

$\frac{x+\frac{x}{dd}}{m}$ and $\frac{2x}{dd}$ will always be equal to the Variation in the common Barometer, and therefore $\frac{2x}{dd} - \frac{x+\frac{x}{dd}}{m} = v$, and by the common Method of Reduction, $x = \frac{v\,m\,d\,d}{2m-dd-1}$: That is, $x : v :: mdd : 2m-dd-1$. Now, if we put $m=14$, and $d=5$, $2m$, $-dd$ and -1 will be as much as $2m$, and therefore $2m-dd-1$ will be equal to nothing; and ſo x being by the Proportion as many Times more than v, as mdd is than nothing, 'tis infinite. And if m be put $=14$, and $d=5$, mdd will be equal to 350, and $2m-dd-1=2$; and therefore the Variations, in this Caſe, will be to thoſe in the common Barometer, as 175 to one.

Pro-

Probably, if the Bore of the Tube FC be made very ſmall, *viz.* about the twentieth Part of an Inch Diameter, the Air will not aſcend through the Water, as it is apt to do through the Mercury in the pendant Barometer; and the Smallneſs of the Bore will not prevent the Water, from moving, near ſo much as it does the Mercury in that Barometer.

There is an Improvement of another Kind in the common Barometer, whereby it is rendered *portable*. The Tube containing the Mercury, inſtead of having its lower End immerged in a Veſſel of that Fluid, has it tied up in a leathern Bag, not quite full of Mercury. And though the external Air cannot get into Bag to ſuſpend the Mercury in the Tube, by preſſing on its Surface, as in the common one; yet it has the ſame Effect by preſſing on the Outſide of the Bag, which, being pliant, yields to the Preſſure, and keeps the Mercury ſuſpended in the Tube at its proper Height. This Bag is generally incloſed in a little Box, through the Bottom of which paſſes a Screw; with this Screw the Bag may be compreſſed, ſo as to force the Mercury up to the Top of the Tube; which keeps it ſteady, and hinders it from breaking the Tube by daſhing againſt the Top when it is carried about, as it otherwiſe would be apt to do.

See more on the Subject of this Diſſertation, *Weidleri* Inſtitutiones Mathemat. p. 608. *Melchior Verdries* Phyſ. Pars ſpecialis, Cap. IV. §. 15. Mr. *Paſchal*'s Traité de l'Equilibre des Liqueurs. *Sinclair*'s Arts magna Gravitatis & Levitatis. *Mariotte*'s Second Eſſay de la Nature de l'Air. Philoſoph. Burgund. Tom. II. p. 850. *Saul*'s Treatiſe on the Barometer. *Regnault's* Philoſoph. Converſat. 22. *Clare*'s Motion of Fluids, p. 141. Mem. de l'Acad. 1705, 1711. Philoſophical Tranſactions N°. 9, 10, 11, 55, 86, 91, 165, 181, 185, 208, 229, 236, 237, 240, 243, 269, 351, 366, 385, 388, 405, 406, 427. *Cotes*'s Hydroſtatical and Pneumatical Lecture. Lect. 7. With ſeveral other Authors referred to in Mr. *Johnſon*'s Quæſtiones Philoſophicæ, Cap. VI. Quæſt. 36, 37.

DISSERTATION V.

Of the Origin of the Winds.

THE Wind is no other, than the Motion of the Air, upon the Surface of the Globe. Some of the Ancients took it to be Air, ruſhing out of the Bowels and Cavities of the Earth: And others thought it an Exhalation from its Surface. But theſe are *Hypotheſes* too chimerical to ſtand in Need of a particular Confutation. Some of the Moderns, who held a *Plenum*, have accounted for it thus: They imagined, that the Air being confined above, as it muſt be, if we ſuppoſe a *Plenum*, would, when more than ordinarily rarefied, or ſtocked with Vapours, drive away the neigbouring Air, in order to make room for itſelf; and by this Means occaſion a Wind. Others, obſerving a conſtant and perpetual eaſterly Wind to blow at the *Equator*, aſcribed its Origin to the diurnal Rotation of the Earth, about its Axis from Weſt to Eaſt; which they thought would occaſion the Air upon its Surface to ſeem to move the contrary Way, being in ſome Meaſure left behind. But, whereas there are Winds, in ſome Places near the *Equator*,

that blow on other Points of the Compaſs (as we ſhall ſee hereafter) this *Hypotheſis* is inſufficient. Beſides, the Air preſſing upon the Surface of the Earth by its Gravity, like other Bodies; and having nothing to hinder it from moving freely along with it, muſt neceſſarily, in Time, acquire an equal Degree of Velocity, and ſo keep Pace with it, all the Way round.

The principal Cauſe of the Wind, or, in other Words, of the Air's moving from Place to Place, upon the Surface of the Earth, is the Atmoſphere's being heated over one Part more than over another. For, in this Caſe, the warmer Air being rarefied, becomes ſpecifically lighter than the reſt, riſes up into the ſuperior Parts of the Atmoſphere, and there diffuſes itſelf every Way; while the neighbouring inferior Air ruſhes in from all Parts at the Bottom, to reſtore the *Æquilibrium*.

Upon this Principle it is, that moſt of the Winds may be accounted for.

To begin with thoſe which blow under the *Equator*.

1. Under the *Equator*, the Wind is always obſerved to blow from the Eaſt Point *.

For,

* For the Reader's Eaſe (who perhaps is not furniſhed with the Philoſophical Tranſactions) I ſhall here inſert by Way of Note, from Dr. *Halley*'s Account, ſo much of the Hiſtory of the Winds, as may be neceſſary for the underſtanding this Theory.

"The

For, ſuppoſing the Sun to continue vertical over ſome one Place, the Air will be moſt rarefied there; and conſequently, the neighbouring

" The univerſal Ocean, ſays he, may moſt properly be di-
" vided into three Parts, *viz.* 1. The *Atlantic* and *Æthiopic*
" Seas. 2. The *Indian* Ocean. 3. The great *South* Sea, or
" the *Pacific* Ocean.

" I. In the *Atlantic* and *Æthiopic* Seas, between the *Tropics*,
" there is a general eaſterly Wind all the Year long, without
" any conſiderable Variation; excepting, that it is ſubject to be
" deflected therefrom, ſome few Points of the Compaſs, towards
" the North, or South, according to the Poſition of the Place.

" 1. Near the Coaſt of *Africa*, as ſoon as you have paſſed the
" *Canary* Iſles, you are ſure to meet a freſh Gale of North-eaſt
" Wind, about the Latitude of twenty-eight Degrees North;
" which ſeldom comes to the Eaſtwards of the Eaſt-north-eaſt,
" or paſſes the North-north-eaſt. This Wind accompanies thoſe
" bound to the Southward, to the Latitude of ten Degrees
" North, and about an hundred Leagues from the *Guinea*
" Coaſt; where, till the fourth Degree of North Latitude,
" they fall into *Calms* and *Tornadoes*, or ſudden Storms.

" 2. Thoſe bound to the *Caribbe* Iſles, find, as they ap-
" proach the *American* Side, that the aforeſaid North-eaſt
" Wind becomes ſtill more and more eaſterly, ſo as ſometimes
" to be Eaſt, ſometimes Eaſt by South, but yet moſt commonly
" to the Northward of the Eaſt, a Point or two, ſeldom more.
" 'Tis likewiſe obſerved, that the Strength of theſe does gra-
" dually decreaſe, as you ſail to the Weſtward.

" 3. That the Limits of the *Trade* and *variable* Winds in
" this Ocean, are farther extended on the *American* Side, than
" the *African*; for, whereas you meet not with this certain
" Wind, till after you have paſs'd the Latitude of twenty-eight
" Degrees on this Side; on the contrary Side it commonly
" holds to thirty, thirty-one, or thirty-two Degrees of Lati-
" tude; and this is verified likewiſe to the Southward of the
" *Æquinoctial*; for near the *Cape of Good Hope*, the Limits of
" the *Trade* Wind, are three or four Degrees nearer the *Line*,
" than on the Coaſt of *Brazil*.

" 4. That

ing Air will ruſh in from every Quarter with equal Force. But, as the Sun is continually ſhifting to the Weſtward, the Part where the Air

" 4. That from the Latitude of four Degrees North, to the " aforeſaid Limits on the South Side of the *Equator*, the Winds " are generally and perpetually between the South and Eaſt, " and moſt commonly between the South-eaſt and Eaſt; ob- " ſerving always this Rule, that on the *African* Side, they are " more ſoutherly, on the *Braſilian* more eaſterly, ſo as to be- " come almoſt due Eaſt, the little Deflection they have being " ſtill to the Southward. In this Part of the Ocean, it has " been my Fortune to paſs a full Year, in an Employment that " obliged me to regard more than ordinarily the Weather, " and I found the Winds conſtantly about the South-eaſt, the " moſt uſual Point South-eaſt by Eaſt: When it was eaſterly, " it generally blew hard, and was gloomy, dark, and ſome- " times rainy Weather: If it came to the Southwards, it was " generally ſerene, and a ſmall Gale next to a Calm; but this " not very common. But I never ſaw it to the Weſtwards of " the South, or Northwards of the Eaſt.

" 5. That the Seaſon of the Year has ſome ſmall Effect on " theſe *Trade* Winds; for that when the Sun is conſiderably to " the Northward of the *Equator*, the South-eaſt Winds, eſpe- " cially in the Streight of this Ocean (If I may ſo call it) be- " tween *Braſil*, and the Coaſt of *Guinea*, do vary a Point or " two to the Southward, and the North-eaſt become more " eaſterly, and, on the contrary, when the Sun is towards the " *Tropic* of *Capricorn*, the South-eaſterly Winds become more " eaſterly; and the North-eaſterly Winds, on this Side the " *Line*, veer more to the Northward.

" 6. That as there is no general Rule, that admits not of ſome " Exception, ſo there is in this Ocean a Tract of Sea, wherein " the ſoutherly and South-weſt Winds are perpetual, *viz.* all " along the Coaſt of *Guinea*, for above five hundred Leagues to- " gether, from *Sierra Leona*, to the Iſle of St. *Thomas*: For " the South-eaſt *Trade* Wind having paſs'd the *Line*, and ap- " proaching the Coaſt of *Guinea* within eighty or an hundred " Leagues, inclines towards the Shore, and becomes South-ſouth- " eaſt; and by Degrees, as you come nearer, it veers about to " South, South-ſouth-weſt, and in with the Land South-weſt,

" and

Air is moſt rarefied, is carried the ſame Way; and therefore the Tendency of all the lower Air, taken together, is greater that Way, than any other.

" and ſometimes Weſt ſouth-weſt. Theſe are the Winds, which are " obſerved on this Coaſt when it blows true; but there are fre- " quent Calms, violent ſudden Guſts, called *Tornadoes*, from all " Points of the Compaſs, and ſometimes unwholeſome foggy " eaſterly Winds, called *Hermitæ*, by the Natives, which too " often infeſt the Navigation of theſe Parts.

" 7. That to the Northwards of the *Line*, between four and " ten Degrees of Latitude, and between the Meridians of *Cape* " *Verde*, and of the eaſtermoſt Iſlands that bear that Name, there " is a Tract of Sea, wherein it were improper to ſay, there is " any *Trade* Wind, or yet a *variable*; for it ſeems condemned to " perpetual Calms, attended with terrible Thunder and Light- " ning, and Rains ſo frequent, that our Navigators from thence " call this Part of the Sea, the *Rains*: The little Winds that " are, being only ſome certain Guſts, of very little Conti- " nuance, and leſs Extent; ſo that ſometimes each Hour you " ſhall have a different Gale, which dies away into a Calm " before another ſucceeds: And in a Fleet of Ships in Sight of " one another, each ſhall have the Wind from a ſeveral Point " of the Compaſs: With theſe weak Breezes, Ships are obliged " to make the beſt of their Way to the Southward, through " the aforeſaid ſix Degrees; wherein it is reported ſome have " been detain'd whole Months for want of Wind. ——

" II. In the *Indian* Ocean, the Winds are partly general, " as in the *Æthiopic* Ocean; partly periodical, that is, half " the Year they blow one Way, and the other half near upon " the oppoſite Points; and theſe Points and Times of ſhifting, " are different in different Parts of this Ocean.

" 1. Between the Latitudes of ten Degrees and thirty De- " grees South, betwen *Madagaſcar* and *Hollandia nova*, the " *General* Trade-Winds about the South-eaſt and by Eaſt, are " found to blow all the Year long, to all Intents and Purpoſes, " after the ſame Manner, as in the ſame Latitudes in the " *Æthiopic* Ocean, as it is deſcribed in the fourth Remark " aforegoing.

" 2. That

other. Thus the Tendency of the Air towards the Weſt, becomes general, and its Parts impelling one another, and continuing to move

" 2. That the aforeſaid South-eaſt Winds extend to within
" two Degrees of the *Equator*, during the Months of *June*,
" *July*, and *Auguſt*, &c. to *November*, at which Time, between
" the South Latitude of three and ten Degrees, being near the
" *Meridian* of the North End of *Madagaſcar*, and between two
" and twelve South Latitude, being near *Sumatra* and *Java*;
" the contrary Winds from the North-weſt, or between the
" North and Weſt, ſet in, and blow for half a Year, *viz.*
" from the Beginning of *December* till *May*: And this *Monſoon*
" is obſerved as far as the *Molucca* Iſles.

" 3. That to the Northward of three Degrees South Lati-
" tude, over the whole *Arabian* and *Indian* Sea, and Gulf of
" *Bengal*, from *Sumatra* to the Coaſt of *Africa*, there is an-
" other *Monſoon*, blowing from *October* to *April*, upon the
" North-eaſt Points: But in the other half Year, from *April*
" to *October*, upon the oppoſite Points of South-weſt and Weſt-
" ſouth-weſt, and that with rather more Force than the other,
" accompanied with dark, rainy Weather; whereas the North-
" eaſt blows clear. 'Tis likewiſe to be noted, that the Winds
" are not ſo conſtant, either in Strength or Point, in the Gulf
" of *Bengal*, as they are in the *Indian* Sea, where a certain
" ſteady Gale ſcarce ever fails. 'Tis alſo remarkable, that
" the South-weſt Winds, in theſe Seas, are generally more
" ſoutherly on the *African* Side, and more weſterly on the
" *Indian*.

" 4. There is a Tract of Sea to the Southward of the
" *Equator*, ſubject to the ſame Changes of the Winds, *viz.*
" near the *African* Coaſt, between it and the Iſland *Madagaſcar*,
" or St. *Laurence*, and from thence Northwards, as far as the
" *Line*; wherein from *April* to *October*, there is found a con-
" ſtant freſh South-ſouth-weſt Wind, which, as you go more
" northerly, becomes ſtill more and more weſterly, ſo as to fall
" in with the Weſt-ſouth-weſt Winds, mentioned before in thoſe
" Months of the Year to be certain to the Northward of the
" *Equator*. What Winds blow in thoſe Seas, for the other
" half Year, I have not yet been able to obtain to my full Satiſ-
" faction: The Account which has been given me, is only this,

" That

move till the next Return of the Sun, ſo much of its Motion as was loſt by his Abſence, is again reſtored, and therefore the eaſterly Wind becomes *Perpetual.*

Some

" That the Winds are much eaſterly hereabouts, and as often to " the North of the true Eaſt, as to the Southward thereof.

" 5. That to the Eaſtward of *Sumatra* and *Malacca,* to the " Northwards of the *Line*; and along the Coaſt of *Camboia* " and *China,* the *Monſoons* blow North and South; that is to " ſay, the North-eaſt Winds are much northerly, and the " South-weſt much ſoutherly. This Conſtitution reaches to the " Eaſtward of the *Philippine* Iſles, and as far northerly as " *Japan*; the northern *Monſoon* ſetting in, in theſe Seas, in " *October* or *November*; and the ſouthern in *May,* blowing all " the Summer Months. Here it is to be noted, that the Points " of the Compaſs from whence the Winds come, in theſe Parts " of the World, are not ſo fixed, as thoſe lately deſcribed; for " the ſoutherly will frequently paſs a Point or two to the Eaſt- " wards of the South, and the northerly as much as to the " Weſtwards of the North, which ſeems occaſioned by the great " Quantity of Land which is interſperſed in theſe Seas.

" 6. That in the ſame Meridians, but to the Southwards of " the *Equator,* being that Tract lying between *Sumatra* and " *Java* to the Weſt, and New *Guinea* to the Eaſt, the ſame " northerly and ſoutherly *Monſoons* are obſerved; but with this " Difference, that the Inclination of the northerly is towards " the North-weſt, and of the ſoutherly towards the South- " eaſt: But the *Plagæ Venti* are not more conſtant here than " in the former, *viz. variable* five or ſix Points. Beſides, the " Times of the Change of theſe Winds are not the ſame, as in " the *Chineſe* Seas, but about a Month, or ſix Weeks later.

" 7. That the contrary Winds do not ſhift all at once, but in " ſome Places the Time of the Change is attended with *Calms,* " in others with *variable* Winds; and it is particularly remark- " able, that the End of the weſterly *Monſoon,* in the Seas of " *China,* are very ſubject to be tempeſtuous. The Violence of " theſe Storms is ſuch, that they ſeem to be of the Nature of " the *Weſt-India* Hurricanes, and render the Navigation of " theſe Parts very unſafe about that Time of Year. Theſe

" Tempeſts

Some are inclined to think, that the continual ſhifting of the Sun to the Weſtward, ſhould produce a weſterly Wind under the *Equator*, by cauſing the Current of the Air from the Weſt to exceed and over-balance that,

" Tempeſts are by our Seamen, uſually term'd the *Breaking up*
" *of the Monſoons.*

" III. The Third Ocean, called *Mare Pacificum*, whoſe Ex-
" tent is equal to that of the other two (it being from the Weſt
" Coaſt of *America* to the *Philippine* Iſlands, not leſs than an
" hundred and fifty Degrees of Longitude) is that which is leaſt
" known to our own, or the neighbouring Nations: That Navi-
" gation that there is on it, is by the *Spaniards*, who go
" yearly from the Coaſt of *New Spain* to the *Manilha*'s: But
" that but by one beaten Tract; ſo that I cannot be ſo particular
" here, as in the other Two. What the *Spaniſh* Authors ſay of
" the Winds, they find in their Courſes; and what is confirmed
" by the old Accounts of *Drake* and *Candiſh*, and ſince by
" *Schooten*, who ſailed the whole Breadth of this Sea, in the
" ſouthern Latitude of fifteen or ſixteen Degrees, is, that there is
" a great Conformity between the Winds of this Sea, and thoſe
" of the *Atlantic* and *Ethiopic*; that is to ſay, that to the North-
" ward of the *Equator*, the predominant Wind is between the
" Eaſt and North-eaſt; and to the Southwards thereof, there
" is a conſtant, ſteady Gale, between the Eaſt and South-eaſt,
" and that on both Sides the *Line*, with ſo much Conſtancy,
" that they ſcarce ever need to attend the Sails; and Strength,
" that it is rare to fail of croſſing this vaſt Ocean in ten Weeks
" Time; which is about an hundred and thirty Miles a Day:
" Beſides, 'tis ſaid, that Storms and Tempeſts are never known
" in theſe Parts, wherefore ſome have thought it might be as
" ſhort a Voyage to *Japan* and *China*, to go by the Streights
" of *Magellan*, as by the Cape of *Good Hope*.

" The Limits of theſe *General* Winds are much the ſame as
" in the *Atlantic* Sea, *viz.* about the thirtieth Degree of La-
" titude on both Sides. Beſides, a farther Analogy between the
" Winds of this Ocean, and the *Ethiopic*, appears in that,
" that upon the Coaſts of *Peru*, they are always much ſoutherly,
" like as they are found near the Shores of *Angola*.

which

which oppoſes it from the Eaſt. For, whereas the eaſtern Air retains its Heat ſome time after the Sun is removed from it, it muſt always be rarefied to a greater Degree, and alſo to a greater Diſtance from the Place to which the Sun is vertical, than the weſtern Air is; and therefore the weſtern Air, being more ponderous, ſhould be an Over-balance for the eaſtern, and drive the Current before it.

But it is to be obſerved, that we are not to conſider the Point to which the Sun is vertical, but the Point of greateſt Rarefaction (which, upon Account of the Sun's Motion to the Weſtward, lies always to the Eaſtward); and then ſee, which Side of the Column of Air, incumbent over that Point, ſuſtains the greater Preſſure from the neighbouring Columns. Now, although the Air is rarefied even farther to the Eaſt of this Point, than to the Weſt, yet ſtill, if we ſuppoſe the Point to keep its place, the Air over it will ſuſtain an equal Degree of Preſſure on each Side. For, ſince no Column can be aſſigned on the weſtern Side, but one alſo on the eaſtern, may be found under an equal Degree of Rarefaction, and therefore of the ſame ſpecific Gravity: and ſince Fluids of equal Heights, and the ſame ſpecific Gravities (whatever be the Breadth of their Columns) preſs equally againſt equal Objects, (Chap. I. §. 9.) 'tis very evident, that the Column of Air, over the

Point of greateſt Rarefaction, is preſſed equally both Ways; and ſo, upon this Suppoſition, each Wind will blow towards that Point with equal Force. But, if we ſuppoſe the Point of greateſt Rarefaction to ſhift towards the Weſt, we ſhall find, that this *Æquilibrium* will by that Means be deſtroyed, and the Motion of the Air (upon the whole) determined that Way. For let us conſider any Portion of the weſtern Air approaching towards the Point of greateſt Rarefaction, if that Point ſhifts, in the mean Time, towards the Weſt, then will that Portion reach the ſaid Point ſooner than it otherwiſe would have done; thereby loſing a Part of its Motion, by which Means the weſterly Current will be diminiſh'd. Again, if, while the Eaſt Wind blows towards the Point of greateſt Rarefaction, that Point moves on before it, then will the eaſtern Air have a greater Quantity of Motion, than it otherwiſe would have had; that, which ſhould have been an Impediment to it, being, upon this Suppoſition, in ſome Meaſure withdrawn; and ſo the Eaſt Wind will be augmented. Thus, the Weſt Wind having its Force leſſen'd by the Motion of the Sun, and the Eaſt one being increaſed, the latter at length as it were abſorbs the former, and carries it away in its own Direction.

2. On each Side of the *Equator*, to about the thirtieth Degree of Latitude, the Wind is found

found, to vary from the Eaſt Point, ſo as to become North-eaſt on the northern Side, and South-eaſt on the ſouthern.

The Reaſon of which is, that, as the *equatorial* Parts are hotter than any other, both the northern and ſouthern Air, ought to have a Tendency that Way; the northern Current therefore, meeting in this Paſſage with the eaſtern, produces a North-eaſt Wind on that Side; as the ſouthern Current joining with the ſame, on the other Side the *Equator*, forms a South-eaſt Wind there.

Theſe two Propoſitions are to be underſtood of open Seas, and of ſuch Parts of them as are diſtant from the Land; for near the Shores, where the neighbouring Air is much rarefied, by the Reflection of the Sun's Heat from the Land, it frequently happens otherwiſe, particularly

3. On the *Guinea* Coaſt, the Wind always ſets in upon the Land, blowing weſterly inſtead of eaſterly. This is becauſe the Deſerts of *Africa* lying near the *Equator*, and being a very ſandy Soil, reflect a great Degree of Heat into the Air above them. This therefore being rendered lighter, than that which is over the Sea, the Wind continually ruſhes in upon the Land to reſtore the *Equilibrium*.

4. That Part of the Ocean, which is called the *Rains*, is attended with perpetual Calms, the Wind ſcarce blowing ſenſibly either one

Way or other. (See its Situation deſcribed in Note, Page 119, Remark 7th). For this Tract being placed between the weſterly Wind blowing from thence towards the Coaſt of *Guinea*; and the eaſterly Wind blowing from the ſame Place to the Weſtward thereof, the Air ſtands in *Æquilibrio* between both, and its Gravity is ſo much diminiſhed thereby, that it is not able to ſupport the Vapour it contains, but lets it fall in continual Rain, from whence this Part of the Ocean has its Name.

5. There is a Species of Winds, obſervable in ſome Places within the *Tropics*, called by the Sailors *Monſoons*, which, during ſix Months of the Year, blow one Way; and the remaining ſix the contrary.

The Occaſion of them in general is this: When the Sun approaches the northern *Tropic*, there are ſeveral Countries, as *Arabia*, *Perſia*, *India*, &c. which become hotter, and reflect more Heat than the Seas beyond the *Equator*, which the Sun has left; the Winds therefore, inſtead of blowing from thence to the Parts under the *Equator*, blow the contrary Way; and when the Sun leaves thoſe Countries, and draws near the other *Tropic*, the Winds turn about, and blow on the oppoſite Point of the Compaſs.

The Regularity of theſe Winds making them more than ordinarily uſeful in Navigation, they are from thence called *Trade* Winds.

Winds. As to other Circumſtances relating to them, and the particular Times and Places of the *Monſoons*, &c. See the Hiſtorical Account in the foregoing Note; all which might eaſily be ſolved upon the ſame Principle, had we *Data* to go upon, and were all the ſeveral Circumſtances of Situation, Heat, Cold, *&c.* ſufficiently known *.

From the Solution of the general *Trade* Winds, we may ſee the Reaſon, why in the *Atlantic* Ocean, a little on this Side the thirtieth Degree of North Latitude, or thereabouts, as was obſerved in the foregoing Diſſertation, there is generally a Weſt, or South-weſt Wind. For, as the inferior Air, within the Limits of thoſe Winds, is conſtantly ruſhing towards the *Equator*, from the North-eaſt Point, or thereabouts, the ſuperior Air moves the contrary Way; and therefore after it has reached theſe Limits, and meets with Air, that has little or no Tendency to

* Some have thought, that the Regularity of the general *Trade* Winds is partly owing to the diurnal Motion of the Moon from Eaſt to Weſt. For, as the Sun renders the Air ſpecifically lighter by its Heat, ſo does the Moon by attracting it, in the ſame Manner, as it does the Sea, in raiſing the Tides: But it is to be obſerved, that as the Moon acts with the greateſt Force upon the ſuperior Parts of the Air, and as thoſe ſuperior Parts are unconfined, and therefore more at Liberty to ruſh in, in Order to reſtore the *Æquilibrium*; it will from hence follow, that the ruſhing in of the ſuperior Parts of the Atmoſphere will principally contribute towards reſtoring the *Æquilibrium*; and ſo the Motion, produced below, will be very inconſiderable.

any

any one Point more than to another, it will determine it to move in the ſame Direction with itſelf.

In our own Climate we frequently experience, in calm Weather, gentle Breezes blowing from the Sea to the Land, in the Heat of the Day; which *Phænomenon* is very agreeable to the Principle laid down above: For the inferior Air over the Land being rarefied by the Beams of the Sun, reflected from its Surface, more than that which impends over the Water which reflects fewer, the latter is conſtantly moving on to the Shore, in order to reſtore the *Æquilibrium*, when not diſturbed by ſtronger Winds from another Quarter †.

From what has been obſerved, nothing is more eaſy than to ſee, why the northern and ſouthern Parts of the World, beyond the Limits of the *Trade* Winds, are ſubject to ſuch

† In Confirmation of this, we have an eaſy, and very pertinent Experiment, related by Mr. *Clare*, in his *Motion of Fluids*. "Take, *ſays he*, a large Diſh, fill it with cold Water; "into the Middle of this put a Water-Plate, filled with warm "Water. The firſt will repreſent the Ocean; and the other "an Iſland, rarefying the Air above it. Blow out a Wax "Candle, and if the Place be ſtill, on applying it ſucceſſively "to every Side of the Diſh, the fuliginous Particles of the "Smoak, being viſible and very light, will be ſeen to move "towards the Plate, and riſing over it, point out the Courſe "of the Air from Sea to Land. Again, if the ambient Water "be warmed, and the Plate filled wiih cold Water, let the "ſmoaking Wick of the Candle be held over the Plate, and "the contrary will happen.

Variety

Variety of Winds. For the Air, upon Account of the leſſer Influence of the Sun in thoſe Parts, being undetermined to move towards any fixed Point, is continually ſhifting from Place to Place, in order to reſtore the *Æquilibrium*, wherever it is deſtroyed; whether by the Heat of the Sun, the riſing of Vapours, or Exhalations, the melting of Snow upon the Mountains, and a great Variety of other Circumſtances, more than can be eaſily enumerated.

We are told by Hiſtorians, of certain Caves that emit Wind; if ſo, it is when the included Air is rarefied by Heat, and therefore ruſhes out for want of Room; or, when the Preſſure of the external Air, incumbent upon the Mouth of the Cave, is diminiſhed, and ſo permits the internal Air to dilate itſelf, and iſſue out.

For more on this Subject, ſee *Nieuwentyt*'s Religious Philoſopher. *Regnault*'s Philoſophical Converſations. *Clare*'s Motion of Fluids. *Martin*'s Philoſophical Grammar. And the Authors referred to in Mr. *Johnſon*'s Quæſtiones Philoſoph. Cap. IV. Quæſt. 1. 2.

DISSERTATION VI.

Of the Formation and Aſcent of Vapours, and their Reſolution into Rain, Snow, *and* Hail.

THAT Vapours are raiſed from the Surface of Water by the Action of the Sun's Heat, is agreed on by all: But the Manner in which this is done, has ever been a Controverſy among Philoſophers; neither is it at this Time ſufficiently explained by any one.

If we conſult a *Carteſian* upon this Matter, he immediately tells us, that, by the Action of the Sun upon the Water, ſmall Particles of the Water, are formed into hollow Spheres, filled with *Materia Subtilis*, and by that Means becoming lighter than an equal Bulk of Air, are eaſily buoyed up in it. But, as this *Materia Subtilis* is only a Fiction, this Solution is not to be regarded.

Dr. *Nieuwentyt*, and ſeveral other Philoſophers, who maintain, that Fire is a particular Subſtance, diſtinct from other Matter, account for the Formation and Aſcent of Vapours thus: They ſay, that the Rays of the Sun, or Particles of Fire ſeparated from them, adhering to Particles of the Water, make up

up little Bodies, lighter than an equal Bulk of Air; which therefore, by the Laws of Hydroſtatics, will aſcend in it, till they come to an Height where the Air is of the ſame ſpecific Gravity with themſelves. And, that Rain is produced by the Separation of the Particles of the Fire from thoſe of the Water; which laſt, being then left without Support, can no longer be ſuſtained by the Air, but falls down in Drops of Rains *.

This Opinion is liable to the following Difficulties; *Firſt*, Fire has never been yet proved to be a diſtinct Element, or a particular Subſtance †; and the Change of Weight in Bodies in chymical Preparations, heretofore thought to ariſe from the Adheſion of Particles of Fire, is found to proceed from the Adheſion of Particles of Air §.

Secondly, Should the above-mentioned Suppoſition be allowed, the fiery Particles, which are joined to the watery ones to buoy them up, muſt be conſiderably large, or elſe a very great Number muſt fix upon a ſingle Particle of Water; and then a Perſon being on the Top of an Hill in a Cloud, would be ſenſible of the Heat, and find the Rain produced from that Vapour, much colder than the Vapour it-

* See *Nieuwentyt*'s Religious Philoſopher, Contempl. 19.

† See the Authors referred to in Mr. *Johnſon*'s Quæſtiones Philoſoph. Cap. I. Quæſt. 30.

§ By Dr. *Hales*, in his *vegetable Statics*.

ſelf: whereas the contrary is evident to our Senſes; the Tops of Hills, though in the Clouds, being much colder than the Rain which falls below.

Beſides, the Manner in which the Particles of Water ſhould be ſeparated from thoſe of the Fire, ſo as to fall in Rain, is not eaſily to be conceived.

The moſt generally received Opinion is, That by the Action of the Sun, on the Surface of the Water, the aqueous Particles become formed into Bubbles, filled with a *Flatus*, or *warm Air*, which renders them ſpecifically lighter than common Air, and makes them riſe therein, till they meet with ſuch as is of the ſame ſpecific Gravity with themſelves *. But I aſk,

Firſt, How comes the Air in the Bubbles to be ſpecifically lighter than that without, ſince the Sun's Rays, which act upon the Water from whence they raiſed, are equally denſe over all its Surface?

Secondly, If it could be poſſible for rarer Air to be ſeparated from the denſer ambient Air, to form the Bubbles (as Bubbles of ſoaped Water are blown up by warm Air from the Lungs, whilſt the ambient Air is colder and denſer) what would hinder the external Air from reducing that, which is incloſed in the Bubbles, immediately to the ſame Degree of

* Philoſophical Tranſactions, N°. 192.

Cold-

Coldneſs, and ſpecific Gravity with itſelf; (Cold being readily communicated through ſuch thin Shells of Water). By which means, the Bubbles would become ſpecifically heavier than the circumambient Air, and would no longer be ſupported therein; but fall down, almoſt as ſoon as they were formed?

Thirdly, If we ſhould grant all the reſt of the Suppoſition, yet the following Difficulty will ſtill remain. If Clouds are made up of Bubbles of Water filled with Air, why do not thoſe Bubbles always expand, when the ambient Air is rarefied, and preſſes leſs upon them than it did before; and why are they not condenſed, when the ambient Air is condenſed by the Accumulation of the ſuperior Air? But if this Condenſation and Rarefaction ſhould happen to them, the Clouds would always contiuue at the ſame Height, contrary to Obſervation; and we ſhould never have any Rain.

The two laſt Opinions are more largely examined by Dr. *Deſaguliers* in the Philoſophical Tranſactions N°. 407. After which he endeavours to eſtabliſh one of his own.

He obſerves, with Sir *Iſacc Newton*, that, when by Heat or Fermentation the Particles of a Body are ſeparated from their Contact, their repulſive Force grows ſtronger, and the Particles exert that Force at greater Diſtances; ſo that the ſame Body ſhall be expanded into a very large Space, by becoming fluid; and

may ſometimes take up more than a Million of Times the Room it did in a ſolid and incompreſſible State. "Thus, ſays he, if the "Particles of Water are turned into Vapour, "by repelling each other ſtrongly, and repel "Air more than they repel each other; Ag-"gregates of ſuch Particles, made up of Va-"pour and Vacuity, may riſe in Air of different "Denſities, according to their own Denſity "depending on their Degree of Heat." He obſerves farther, that Heat acts more powerfully on Water, than on common Air; for that the ſame Degree of Heat, which rarefies Air two Thirds, will rarefy Water near fourteen thouſand Times, changing it into Steam or Vapour as it boils it. And in Winter, that ſmall Degree of Heat, which in Reſpect of our Bodies appears cold, will raiſe a Steam or Vapour from Water, at the ſame Time that it condenſes Air. Laſtly, he obſerves, That the Denſity and Rarity of this Vapour depends chiefly on its Degree of Heat, and but little on the Preſſure of the circumambient Air. From all which he infers, that the Vapour being more rarefied near the Surface of the Earth, than the Air is there by the ſame Degree of Heat, muſt neceſſarily be buoyed up into the Atmoſphere; and ſince it does not expand itſelf much, though the Preſſure of the incumbent Air grows leſs, at length it finds a Place where the Atmoſphere is of the ſame ſpecific

Gravity

Gravity with itſelf, and there floats, till by ſome Accident or other, it is converted again into Drops of Water, and falls down in Rain.

And to ſhew that Air is not neceſſary for the Formation of Steam or Vapour, he gives us this Experiment.

" ABCD (*Fig.* 37.) is a pretty large Veſ-
" ſel of Water, which muſt be ſet upon the
" Fire to boil. In this Veſſel muſt be ſuſpend-
" ed the Glaſs Bell E, made heavy enough
" to ſink in Water; but put in, in ſuch a
" Manner, that it be filled with Water when
" upright, without any Bubbles of Air at its
" Crown within, the Crown being all under
" Water. As the Water boils, the Bell will
" by Degrees be emptied of its Water, the
" Water in the Bell being preſſed down by
" the Steam which riſes from it; but, as that
" Steam has the Appearance of Air, in Order
" to know whether it be Air or not, take the
" Veſſel off the Fire, and draw up the Bell
" by a String faſtened to its Knob at Top,
" till only the Mouth remains under Water;
" then as the Steam condenſes by the cold Air
" on the Outſide of the Bell, the Water will
" riſe up into the Bell at F, quite to the Top,
" without any Bubble above it; which ſhews,
" that the Steam, which kept out the Water,
" was not Air."

This Hypotheſis, however plauſible it may appear, is attended with Difficulties, as well as the other. For,

Firſt, If the repulſive Power of the Particles of Water is ſufficiently augmented by Heat as ſuch (and that by a very ſmall Degree of it) to make them recede from each other, and become ſpecifically lighter than common Air; how comes it to paſs, that all the Particles of Water, as ſoon as, or before it boils, have not their repulſive Forces thus augmented, ſince they are all under a much greater Degree of Heat, than is neceſſary to raiſe Vapour?

Secondly, Allowing that they may riſe off from the Surface of the Water, and float in the circumambient Air, as being lighter than it, why do not their repulſive Forces, as they riſe up into the Air, and the ſuperincumbent Preſſure becomes leſs, drive them to greater Diſtances from each other, and ſo cauſe them to continue lighter than the Air about them at all Heights?

Thirdly, If the Preſſure of the Air about them, when near the Surface of the Earth, is not ſufficient to bring them into ſo cloſe Contact, as to form Drops of Water there, what Force will they find ſufficient for it, when they are carried aloft into a Region of Air, where the Preſſure is not near ſo great? The Doctor hints, that they are formed into Rain, "when "by the great Diminution of the ſpecific Gravity

" vity of the Air about a Cloud, it has a great " Way to fall, in which Caſe, he ſays, the " Reſiſtance of the Air, which increaſes as " the Square of the Velocity of the deſcend- " ing Cloud, cauſes the floating Particles of " Water to come within the Power of each " other's Attraction, and form ſuch big Drops " as, being ſpecifically heavier than any Air, " muſt fall in Rain." But as the inferior Air, from the Cloud to a conſiderable Depth below it, cannot be ſuppoſed to leave it all at once, the Vapours muſt neceſſarily fall all the Way through a reſiſting *Medium*; ſo that the little Velocity the Cloud can acquire, while it is in the Form of Vapour, will never produce a Reſiſtance from the Air greater than the Preſſure which the Vapours ſuſtained below.

Laſtly, The Experiment, brought to make Way for this Hypotheſis, ſhows clearly, that Vapour formed without the Aſſiſtance of Air, is immediately condenſed into Water again, as ſoon as it is ſuffered to cool: Which is widely different from what happens to Vapours buoyed up into the colder Regions of the Air, and floating there, till they fall in Rain.

Theſe are all, or the principal *Hypotheſes*, that have been framed for the Solution of this common *Phænomenon*: Which as they ſeem inadequate to the Effects produced, and therefore unſatisfactory, I thought it not amiſs to

ſug-

ſuggeſt to the Reader the chief Difficulties, with which I conceive them to be attended. But as it is eaſier to pull down, than to build up, to overturn a weak *Hypotheſis*, than to raiſe and ſupport a ſtrong and *ſufficient* one; ſo, I muſt own, in this Caſe, I can think of no Way of accounting for the *Riſe* of Vapours, according to the received Principles of Philoſophy, or ſay *wherein* their Nature conſiſts. Upon this Account it is impoſſible I ſhould give a Philoſophical Account of their Reſolution into Rain. It muſt ſuffice juſt to mention the Cauſes which are obſerved to produce that Change.

The firſt is, Part of the Air beneath them being carried away by contrary Winds blowing from the ſame Place *, the Remainder becomes too light to buoy them up, and ſo the upper ones, in all Probability, precipitate down upon the lower ones, unite with them, and forms Drops of Rain †. Another is great Quan-

* Perhaps it may be thought, that when the Air, which impends over any Place, is carried away from thence by contrary Winds, the Vapours which float in it ſhould be carried away too; and ſo the few that remain ſhould be eaſily ſupported; or, if they fall, ſhould not produce much Rain.

Now, in anſwer to this, it muſt be conſidered, that as the inferior Air is carried away from any Place by contrary Winds, the Height of the Atmoſphere is diminiſhed thereby; wherefore, in all Probability, the ſuperior Air ruſhes in by a contrary Current to fill up the Vacuity at the Top, which bringing in its Contents of Vapour affords a continual Supply for the Rain that falls.

† A remarkable Inſtance we have of this, in that Part of the *Atlantic* Ocean, which the Sailors call the *Rains*, (ſee Diſſert. V.) from

Quantites of them, being driven by the Winds againſt the Sides of Mountains, are thereby made to coaleſce, and ſo conſtitute Rain *.

It

from the frequent Rains that fall there: the Occaſion of which is, that the Atmoſphere is diminiſhed by continual contrary Winds blowing from thence, ſo that it is not able to ſuſtain the Vapour it receives.

* Upon this depends the Difference of the Seaſons of the Year at *Malabar* and *Coromandel* in the *Eaſt-Indies*, and at *Jamaica* in the Weſt. See Dr. *Gordon*'s Diſcourſe on the Cauſes of the Change of Weather, Philoſophical Tranſactions, N°. 17——

" the Rivers of *Indus* and *Ganges*, ſays he, where they enter the " Ocean, contain between them a large *Cherſoneſus*, which is di- " vided in the Middle by a Ridge of Hills, which they call the " *Gate*, which run along from Eaſt to Weſt, and quite through " to Cape *Comori*. On the one Side is *Malabar*, and on the other " *Coromandel*. On the *Malabar* Side, between that Ridge of " Mountains and the Sea, it is after their Appellation Summer " from *September* till *April*; in which Time it is always a clear " Sky, without once, or very little Raining. On the other Side " the Hills, on the Coaſt of *Coromandel*, it is at the ſame Time " their Winter, every Day and Night yielding Abundance of " Rain, and from *April* to *September* it is, on the *Malabar* Side " their Winter, and on the other Side their Summer: So that " in little more than twenty Leagues Journey in ſome Places, as " where they croſs the Hills to St. *Thomas*, on the one Side of " the Hill you aſcend with a fair Summer; on the other you " deſcend with a ſtormy Winter. The like is ſaid to be at Cape " *Razalgate* in *Arabia*. And Dr. *Tropham* relates the ſame of " *Jamaica*, intimating that there is a Ridge of Hills which runs " from Eaſt to Weſt, through the midſt of the Iſland, and that " the Plantations on the South Side of the Hills have, from " *November* to *April*, a continual Summer, whilſt thoſe on the " North Side have as conſtant a Winter, and the contrary from " *April* to *November*.

" From theſe and ſuch like Accounts it ſeems evident, that a " bare leſſening of the Atmoſphere's Gravity will not occaſion " Rain, but that there is alſo needful either a ſudden Change of " Winds, or a Ridge of Hills to meet the Current of the Air and " Vapours, whereby the Particles of the Vapours are driven to- " gether, and ſo fall down in Drops of Rain. and hence it is,

It is generally thought, That if the Vapours in their Deſcent paſs through a Region of Air ſufficiently cold, they are there frozen into Icicles,

" that whilſt the Wind blows from the North-eaſt, *viz.* from " *November* to *April* (ſee the Account of the Monſoons in the foregoing Diſſertation) " there are continual Rains in the " northerly Plantations of *Jamaica*, and on the Side of *Coroman-* " *del* in the *Eaſt-Indies*, becauſe the Winds beat againſt that Side " of the Hills; and ſo there is fair Weather on the other Side " of theſe Hills, in *Malabar* and in the ſouthern Plantations of " *Jamaica*, there being no Winds to drive the Vapours toge- " ther. But in the ſoutherly Monſoons, *viz.* from *April* to *No-* " *vember*, *Malabar* and the ſoutherly Plantations of *Jamaica* " have Floods of Rain, the Wind beating againſt that Side of " the Hills, whilſt in *Coromandel*, and the other Side of *Jamaica*, " there is fair and clear Weather.

" This ſerves alſo to clear the *Singularity* of *Seaſons* in *Peru*, " beyond any other Parts of the Earth, and ſeems to be aſſigned " by *Acoſta* as the Cauſe of it. *Peru* runs along from the *Line* " Southwards about a thouſand Leagues. It is ſaid to be divided " into three Parts, long and narrow, which they call *Lanos*, " *Sierras*, and *Andes*; the *Lanos*, or Plains, run along the South- " Sea Coaſt; the *Sierras* are all Hills with ſome Vallies; and " the *Andes* ſteep and craggy Mountains. The *Lanos* have ſome " ten Leagues in Breadth, in ſome Parts leſs, and in ſome more; " the *Sierras* contain ſome twenty Leagues in Breadth, the *Andes* " as much, ſometimes more, ſometimes leſs; they run in Length " from North to South, and in Breadth from Eaſt to Weſt. This " Part of the World is ſaid to have theſe remarkable Things: " 1. All along the Coaſt, in the *Lanos*, it blows continually with " one only Wind, which is South and South-weſt, contrary to " that which uſually blows under the torrid Zone. 2. It never " rains, thunders, ſnows, or hails in all this Coaſt, or *Lanos*, " though there falls ſometimes a ſmall Dew. 3. Upon the " *Andes* it rains almoſt continually, though it be ſometimes " more clear than other. 4. In the *Sierras*, which lie be- " tween both Extreams, it rains from *September* to *April*, but " in the other Seaſons it is more clear, which is when the Sun " is fartheſt off, and the contrary when it is neareſt. Now " the Reaſon of all ſeems to be this; The eaſtern Breezes, " which blow conſtantly under the *Line*, being ſtopp'd in their

" Courſe

Icicles and form Snow. But this Opinion ſeems to be falſe; becauſe it frequently ſnows when the Barometer is high, at which Time the Vapours cannot begin to fall. It is therefore more probable, that they are firſt frozen into Icicles, and by that means ſhooting forth into ſeveral Points every Way from the Center (agreeably to the Nature of Freezing) loſe their Form; and ſo becoming ſpecifically heavier than Air fall down, and in their Paſſage, ſeveral being congealed together, form Fleeces of Snow †.

Hail is evidently no other than Drops of Rain congealed into Ice. This happens, when in their Paſſage through the inferior Air, they

" Courſe by the *Sierras* and *Andes*, and yet the ſame Breezes " being to be found in the South Sea beyond *Peru*, as appears " by the eaſy Voyages from *Peru* to the *Philippines*, a Current " of Wind blows from the South on the Plains of *Peru*, to ſup- " ply the eaſtern Breeze on the South Seas, and there being but " one conſtant Gale on theſe Plains, and no contrary Winds or " Hills for it to beat upon, this ſeems to be the Reaſon why the " Vapours are never or very ſeldom driven into Rain. And " the *Andes* being as high perhaps in many Places as the Va- " pours aſcend in the higheſt Degree of the Atmoſphere's Gra- " vity, this may probably be the Reaſon. why the eaſtern " Breeze, beating conſtantly againſt theſe Hills, occaſions Rain " upon them at all Seaſons of the Year. And the *Sierras* being " it ſeems lower than the *Andes*, therefore from *September* to " *April*, when the Sun is neareſt, and ſo the Atmoſphere's " Gravity leſs, and the Vapours lower, they are driven againſt " the *Sierras* into Rain."

The like is to be ſaid of other Countries. They are all, *cæteris paribus*, more or leſs rainy, as they are more or leſs mountainous.

Ægypt, which is quite without Mountains, has ſeldom or never any Rain; but is plentifully watered by the *Nile*, which yearly riſes above its Banks, and overflows the Country.

† See a Diſcourſe on the Nature of Snow, Philoſophical Tranſactions N°. 92.

meet with *nitrous* Particles, which are known to contribute greatly to Freezing. Their Magnitude is owing to a freſh Acceſſion of Matter, as they paſs along. Hence we ſee the Reaſon why Hail is ſo frequent in Summer, becauſe at that Time greater Quantities of Nitre are exhaled from the Earth, and float up and down in the Air.

If the Vapours, after they are exhaled from off the Waters, do not riſe very high in the Atmoſphere, but hover near the Surface of the Earth, they then conſtitute what we call a Fog. And, if they aſcend higher, they ſtill appear in the ſame Form to thoſe, who, being upon the Tops or Sides of Mountains, are at an equal Height with them; though to thoſe, who are below, they appear as Clouds.

If they fall to the Earth, without uniting into Drops large enough to be called Rain, they are then ſaid to fall in Dew.

See farther on this Subject, *Derham*'s Phyſ. Theolog. Book I. Chap. 3, and Book II. Chap. 5. Spectacle de la Nature, Dialog. 21, and 23. *Nieuwentyt* Contempl. 19. *Clare*'s Motion of Fluids. *Regnault*, Vol. III. Converſat. 7. *Muſſchenbroek* Epitom. Phyſ. Mathemat. Par. II. Cap. 24. *Melchior Verdries* Phyſic. Pars ſpecial. Cap. V. §. 8. And the Authors referred to in Mr. *Johnſon*'s Queſtiones Philoſoph. Cap. IV. Quæſt. 7.

DIS-

DISSERTATION VII.

Of the Cauſes of Thunder and Lightning, and of the Aurora Borealis.

THOSE Philoſophers, who maintain that Vapours are buoyed up into the Air, by Particles of Fire adhering to them (as explained in the foregoing Diſſertation) account for the *Phænomena* of Thunder and Lightning. in the following Manner, They ſuppoſe, that from the Particles of Sulphur, Nitre, and other combuſtible Matter, which are exhaled from the Earth, and carried into the higher Regions of the Atmoſphere, together with the aſcending Vapours, is formed an inflammable Subſtance; which, when a ſufficient Quantity of fiery Particles is ſeparated from the Vapour by the Colliſion of two Clouds, or otherwiſe, takes Fire, and ſhoots out into a Train of Light, greater or leſs, according to the Strength and Quantity of the Materials.

The Opinion is falſe for the Reaſons mentioned in the foregoing Diſſertation, which plainly ſhow, that it is impoſſible the Vapours ſhould be attended with ſuch fiery Particles, as is here ſuppoſed.

Neither

Neither have we Occaſion to fly to ſuch an *Hypotheſis*; for, as Vapours exhaled from the Surface of the Water are carried up into the Atmoſphere: in like Manner, the *Effluvia* of ſolid Bodies are continually aſcending thither: Now we find by Experiment, that there are ſeveral inflammable Bodies, which, being mixed together in due Proportion, will kindle into Flame by Fermentation alone, * without the Help of any fiery Particles †. When therefore

* See the Theory of Fermentation explained in the following Diſſertation.

† Monſieur *Lemery* having covered up in the Earth about fifty Pounds of a Mixture compoſed of equal Parts of Sulphur, and Filings of Iron tempered with Water; after eight or nine Hours Time, the Earth, where it was laid, vomited up Flames. Hiſt. de l'Acad. 1700. p. 574.

From this Experiment we ſee the true Cauſe of the Fire of *Ætna* and *Veſuvius*, and other burning Mountains. They probably are Mountains of Sulphur, and ſome other Matter proper to ferment with it, and take Fire. From like Cauſes proceeds the Heat of Bath-waters, and other hot Springs.

Mix a ſmall Quantity of Gun-Powder with Oyl of Cloves, pour gently upon this Mixture, two or three times as much Spirit of Nitre, and you will obſerve a bright Inflammation ſuddenly ariſing from it. A Mixture of the two Fluids alone will take Fire; the Powder is added only to augment the Inflammation.

Take two Pounds of Nitre, or refined Salt Petre well dried and reduced to the fineſt Powder, with a Pound of Oyl of common Vitriol: From this Mixture may be drawn by Diſtillation a Spirit of Nitre capable of inflaming Oyl of Turpentine. Mem. de l'Acad. 1726, p. 97, *&c.* Put into a Glaſs an Ounce of this Spirit of Nitre, with an Ounce of Oyl of Vitriol; pour upon it an equal Quantity of Oyl of Turpentine, and a very fine Flame will ariſe ſuddenly with a great Exploſion. When the Liquors are freſh the Effect is much greater. If we mix a Dram of the Spirit of Nitre and three of Oyl of Turpentine, with only one of the Spirit

fore there happens to be a proper Mixture of the *Effluvia* of ſuch Bodies floating in the Air, they ferment, kindle, and flaſhing like Gun-powder, occaſion thoſe Exploſions, and Streams of Fire, which we call Thunder and Lightning.

As to the particular Species of the *Effluvia*, which compoſe this Mixture, that cannot exactly be determined; they are thought to be chiefly ſulphureous and nitrous: *ſulphureous*, becauſe of the ſulphureous Smell which Lightning generally leaves behind it, and of that ſultry Heat in the Air which is commonly the Fore-runner of it: *nitrous*, becauſe we don't know of any Body ſo liable to a ſudden and violent Exploſion, as Nitre is *.

The

Spirit of Vitriol, the Mixture will take Fire immediately. If the ſame Experiment be made with the Balm of *Mecca*, a ſudden Flame will ariſe, with a Noiſe like that of the Report of a Gun.

There are two celebrated Experiments of this Kind, though they do not come up exactly to the preſent Purpoſe, becauſe they will not ſucceed, unleſs the Ingredients be firſt heated, the one of *Aurum fulminans*, and the other of *Pulvis fulminans*. The firſt is a Mixture of Salt of Tartar, and Gold diſſolved by *Aqua Regia*. A ſmall Quantity of this, if put into a Braſs Spoon, and heated with the Flame of a Candle, cauſes a ſudden Noiſe reſembling that of Thunder; and goes off with great Violence. The other is a Mixture of three Parts of Nitre, two of Salt of Tartar, and one of Sulphur. This Mixture when ſet upon the Fire, and warmed to a certain Degree, is diſſipated all on a ſudden with great Thundering, like the *Aurum fulminans*.

See an Account of Exhalations taking Fire of their own Accord in Coal-Pits. *Power*'s Experimental Philoſophy, p. 62, and 181.

* Dr. *Liſter* is of Opinion, That the Matter both of Thunder and Lightning, and alſo of Earthquakes, is the *Effluvia* of the *Pyrites*,

The Effects of Thunder and Lightning are owing to the ſudden and violent Agitation the Air is put into thereby, together with the Force of the Exploſion *; and not to Thunderbolts falling from the Clouds, as ſuppoſed by the Vulgar †.

Pyrites; as he does, that the Matter of *Vulcano*'s is the *Pyrites* itſelf. This is a Mineral that emits copious Exhalations, and is exceedingly apt to take Fire upon the Admiſſion of Moiſture. See the Doctor's Defence of his Notion in the Philoſophical Tranſactions, N°. 157. He thinks this may be the Reaſon why *England* is ſo little troubled with Earthquakes, and *Italy*, and almoſt all Places round the *Mediterranean* Sea, ſo very much, *viz.* becauſe the *Pyrites* are rarely found in *England*; and where they are, they lie very thin, in Compariſon of what they do in thoſe Countries: as the vaſt Quantity of Sulphur, emitted from the burning Mountains there, ſeems to ſhew.

* Lightning is ſaid to have diſſolved Silver, without burning the Purſe it was in; and to have melted the Sword, without touching the Scabbard, and the like. The Occaſion of this may poſſibly be, that the Matter of the Exhalation may be ſo ſubtle and penetrating, that, as we ſee it happens with *Aqua Fortis*, or *volatile Salts*, it may paſs through ſoft Bodies without altering their Texture, while it ſpends it whole Force on hard ones, in which it finds the greater Reſiſtance.

† Some are inclined to think, that Thunderbolts are artificial, and that they were applied by the Ancients to ſome Uſe. What confirms them in their Opinion, is, that they are found more frequently where Sepulchres have been, than in other Places. And, as it was the Cuſtom of the Ancients to have their Arms buried with their Aſhes, they think they might be of ſome Uſe in War. Some are of Opinion, they were uſed in Sacrifices. See *Melchior Verdrie*'s Phyſic. Pars ſpecial Cap. V. §. 9. *Wedelius* Exercit. Med. Philol. Cont. II. Dec. I. p. 103. *Schminckius* Prof. Marpurg. Diſſertat. de Urnis Sepulchralibus, & Armis Lapideis, A. 1714. *Herman Nunningius* Sepulchret. Weſtphal. Mimigard. Gentil. p. 44. *Jo. Henr. Coharſen* Oſſileg. Hiſtor. Phyſic. p. 44.

The

The Diſtance the Thunder is from us, may nearly be eſtimated by the Interval of Time between our ſeeing the Lightning, and hearing the Thunder. For, as the Motion of Light is ſo very quick, that the Time it takes up, in coming to us from the Cloud, is not perceptible; and as that of Sound is about a thouſand Feet in a Second; allowing a thouſand Feet for every Second, that paſſes between our ſeeing the one, and hearing the other; we have the Diſtance of the Cloud, pretty nearly, from whence the Thunder comes.

We ſometimes ſee Flaſhes of Lightning, though the Sky be clear and free from Clouds; in this Caſe they proceed from Clouds, that lie immediately below our Horizon.

Of Affinity with the *Phænomena* of Lightning are thoſe of the *Aurora Borealis*, or *Northern Lights*, which, of late Years, have very frequently appeared in our Climate *. Theſe Lights differ ſo much from each other, that to give a Deſcription of one alone, would not be

* *Phænomena* of this Kind are reported to have been very frequent in *Greenland*, *Iceland*, and *Norway*, Countries near the Pole. The only ones, that are upon Record, as having appeared in *England*, before that of *March* the 6th, $17\frac{5}{18}$, are thoſe of *January* the 30th, 1560, *October* the 7th, 1564, *November* 14th and 15th, 1574, and a ſmall one ſeen near *London* on the 9th of *Auguſt*, 1708. On *November* the 16th, 1707, a ſmall one appeared in *Ireland*. Since that of *March* the 6th, $17\frac{15}{18}$, they have been, and ſtill continue very common.

ſufficient to acquaint the Reader with all the Circumſtances wherewith they are attended. I ſhall therefore collect together ſuch *Phænomena*, as have been moſt generally obſerved, and reduce them to the ten following Propoſitions, adding in the Notes, by Way of *Specimen*, a full Account of that moſt remarkable *Aurora*, which was ſeen *March* the 6th $17\frac{15}{16}$, as it was laid before the *Royal Society* by Dr. *Halley*, at their Requeſt †.

The

† "On *Tueſday* the 6th of *March*, in the Year 1716 (the Afternoon having been very ſerene and calm, and ſomewhat warmer than ordinary) about the Time it began to grow dark (much about ſeven of the Clock) not only in *London*, but in all Parts of *England*, where the Beginning of this wonderful Sight was ſeen; out of what ſeemed a duſky Cloud, in the North-eaſt Parts of the Horizon, and ſcarce ten Degrees high, the Edges whereof were tinged with a reddiſh Yellow, like as if the Moon had been hid behind it, there aroſe very long luminous Rays, or Streaks perpendicular to the Horizon, ſome of which ſeemed nearly to aſcend to the *Zenith*. Preſently after, that reddiſh Cloud was ſwiftly propagated along the northern Horizon into the North-weſt, and ſtill farther weſterly; and immediately ſent forth its Rays from all Parts, now here, now there, they obſerving no Rule or Order in their riſing. Many of thoſe Rays, ſeeming to concur near the *Zenith*, formed there a *Corona*, or Image, which drew the Attention of all Spectators. Some likened it to that Repreſentation of Glory, wherewith our Painters in Churches ſurround the Holy Name of God. Others to thoſe radiating *Stars*, wherewith the Breaſts of *Knights* of the Order of the *Garter* are adorned. Many compared it to the *Concave* of the great *Cupola* of St. *Paul's* Church, diſtinguiſhed with Streaks alternately light and obſcure, and having in the Middle a Space leſs bright than the reſt, reſembling the Lanthorn. Whilſt others, to expreſs as well the Motion as Figure thereof, would have it to be like the Flame in an Oven, reverberated and rolling againſt the arched

"Roof

The moſt general *Phænomena* of an *Aurora Borealis* are theſe that follow.

1. In the northern Parts of the *Horizon*, there is commonly the Appearance of a very black

" Roof thereof: Some thought it liker to that tremulous Light, " which is caſt againſt the Cieling by the Beams of the Sun, re- " flected from the Surface of the Water in a Baſon, that's a little " ſhaken. But all agree, that this *Spectrum* laſted only a few " Minutes, and exhibited itſelf variouſly tinged with Colours, " Yellow, Red, and a duſky Green: Nor did it keep in the " ſame Place; for when firſt it began, it appeared a little to the " Northwards of the *Zenith*, but by Degrees declining towards " the South, the long *Striæ* of Light, which aroſe from all " Parts of the Northern Semicircle of the *Horizon*, ſeemed to " meet together, not much above the Head of *Caſtor*, or the " northern *Twin*, and there ſoon diſappeared.

" After the firſt *Impetus* of the aſcending Vapour was over, " the *Corona* appeared no more; but ſtill, without any Order, " as to Time or Place, or Size, luminous *Radii*, like the for- " mer, continued to ariſe perpendicularly, now oftener, and " again ſeldomer; now here, now there; now larger, now " ſhorter. Nor did they proceed as at firſt, out of a Cloud, " but oftener would emerge at once out of the pure Sky, which " was more than ordinary ſerene and ſtill. Nor were they all " of the ſame Form. Moſt of them ſeemed to end in a Point " upwards, like erect Cones; others like truncate Cones, or " Cylinders, ſo much reſembling the long Tails of Comets, " that at firſt Sight, they might well be taken for ſuch. Some " of thoſe Rays would continue viſible for ſeveral Minutes; " when others, and thoſe the much greater Part, juſt ſhewed " themſelves, and died away. Some ſeemed to have little Mo- " tion, and to ſtand, as it were, fixed among the Stars, whilſt " others, with a very perceptible Tranſlation, moved from Eaſt " to Weſt under the Pole, contrary to the Motion of the Hea- " vens; by which Means they would ſometimes ſeem to run " together, and at other Times to fly one another.

" After this Sight had continued about an Hour and a half, " thoſe Beams began to riſe much fewer in Number, and not near " ſo high; and by Degrees, that diffuſed Light, which had illuſ-

black Cloud; but it is evident that it is no real Cloud, becauſe the ſmalleſt Stars are viſible through it. This apparent Cloud is extended ſometimes farther towards the Weſt, than

" trated the northern Parts of the Hemiſphere, ſeemed to ſub-
" ſide, and ſettling on the Horizon, formed the Reſemblance of
" a very bright *Crepuſculum*. That this was the State of this *Phæ-*
" *nomenon*, in the firſt Hours, is abundantly confirmed by the
" unanimous Conſent of ſeveral. For, by the Letters we have
" received from almoſt all the extreme Parts of the Kingdom,
" there is found very little Difference from what appeared at
" *London* and *Oxford*; unleſs that in the North of *England*,
" and in *Scotland*, the Light ſeemed ſomewhat ſtronger and
" brighter.

" Hitherto I have related the Obſervations of others; as to
" myſelf, I had no Notice of this Matter, till about nine of the
" Clock: I immediately perceived toward the South and South-
" weſt Quarter, that though the Sky was clear, yet it was tinged
" with a ſtrange Sort of Light; ſo that the ſmaller Stars were
" ſcarce to be ſeen, and much as it is when the Moon of four
" Days old appears after Twilight. I perceived at the ſame
" Time a very thin Vapour to paſs before us, which aroſe from
" the preciſe Eaſt Part of the Horizon, aſcending obliquely, ſo
" as to leave the *Zenith* about fifteen or twenty Degrees to the
" Northward. But the Swiftneſs, wherewith it proceeded, was
" ſcarce to be believed, ſeeming not inferior to that of Light-
" ning; and exhibiting, as it paſſed on, a Sort of momentaneous
" *Nubecula*, which diſcover'd itſelf by a very diluted and feint
" Whiteneſs; and was no ſooner formed, but before the Eye
" could well take it, it was gone, and left no Signs behind it.
" Nor was this a ſingle Appearance; but for ſeveral Minutes,
" about ſix or ſeven Times in a Minute, the ſame was again and
" again repeated; theſe Waves of Vapour regulary ſucceeding
" one another, and at Intervals very nearly equal; all of them
" in their Aſcent producing a like tranſient *Nubecula*.

" By this Particular we were firſt aſſured; that the Vapour we
" ſaw, became conſpicuous by its own proper Light, without the
" Help of the Sun's Beams; for theſe *Nubeculæ* did not diſcover
" themſelves in any other Part of their Paſſage, but only between
" the South-eaſt and South, where being oppoſite to the Sun,

" they

than to the Eaſt; ſometimes farther towards the Eaſt, than to the Weſt; and generally takes up a Quarter of the Horizon, more or leſs,

2. The

" they were deepeſt immerſed in the Cone of the Earth's Sha-
" dow; nor were they viſible before or after. Whereas the
" contrary muſt have happened, had they borrowed their
" Light from the Sun,

" On the weſtern Side of the northern Horizon, *viz.* between
" Weſt and North-weſt, not much paſt ten of the Clock, I ob-
" ſerved the Repreſentation of a very bright Twilight, con-
" tiguous to the Horizon, out of which aroſe very long Beams
" of Light, not exactly erect towards the *Vertex*, but ſomething
" declining towards the South; which, aſcending by a quick
" and undulating Motion to a conſiderable Height, vaniſhed in
" a little Time; whilſt others, though at uncertain Intervals,
" ſupplied their Place. But at the ſame Time, through all the
" reſt of the northern Horizon, *viz.* from the North-weſt to
" the true Eaſt, there did not appear any Sign of Light to ariſe
" from, or join to, the *Horizon*; but what appeared to be an
" exceeding black and diſmal Cloud, ſeemed to hang over all
" that Part of it. Yet was it no Cloud, but only the ſerene Sky,
" more than ordinary pure and limpid, ſo that the bright Stars
" ſhone clearly in it, and particularly *Canuda Cygni*, than very
" low in the North: the great Blackneſs manifeſtly proceeding
" from the Neighbourhood of the Light, which was collected
" above it. For the Light had now put on a Form quite different
" from all that we have been deſcribing, and had faſhioned itſelf
" into the Shape of two *Laminæ*, or Streaks, lying in a Poſition
" parallel to the *Horizon*, whoſe Edges were but ill terminated.
" They extended themſelves from the North by Eaſt to the
" North-eaſt, and were each about a Degree broad; the un-
" dermoſt about eight or nine Degrees high, and the other about
" four or five Degrees over it; theſe kept their Places for a long
" Time, and made the Sky ſo light, that I believe a Man might
" eaſily have read an ordinary Print by the Help thereof.

" Whilſt I was viewing this ſurpriſing Light, and expecting
" what was farther to come, the northern End of the upper *La-*
" *mina* by degrees bent downwards, and at length cloſed with
" the End of the other that was under it, ſo as to ſhut up on the
" North Side an intermediate Space, which ſtill continued open

" to

2. The upper Edge of this Cloud (which is ſometimes within leſs than ſix Degrees of the Horizon, and ſometimes forty or fifty above it)

" to the Eaſt. Not long after this, in the ſaid included Space, I " ſaw a great Number of ſmall Columns, or whitiſh Streaks, to " appear ſuddenly erect to the Horizon, and reaching from the " one *Lamina* to the other; which inſtantly diſappearing, were " too quick for the Eye, ſo that I could not judge, whether they " aroſe from the under, or fell from the upper; by their ſudden " Alterations, they made ſuch an Appearance, as might well " enough be taken to reſemble the Conflict of Men in Battle.

" And much about the ſame Time, there began on a ſudden to " appear, low under the Pole, and very near due North, three or " four lucid *Areas*, like Clouds, diſcovering themſelves in the " pure but very black Sky, by their yellowiſh Light. Theſe, as " they broke out at once, ſo after they had continued a few Mi- " nutes, diſappeared as quick, as if a Curtain had been drawn " over them: Nor were they of any determined Figure, but " both in Shape and Size might properly be compared to ſmall " Clouds illuminated by the full Moon, but brighter.

" Not long after this, from above the foreſaid two *Laminæ*, " there aroſe a very great *Pyramidal* Figure, like a Spear, ſharp " at the Top, whoſe Sides were inclined to each other, with an " Angle of about four or five Degrees, and which ſeemed to " reach up to the *Zenith*, or beyond it. This was carried with " an equable, and not very ſlow Motion, from the North- " eaſt where it aroſe, into the North-weſt, where it diſappeared, " ſtill keeping in a perpendicular Situation, or very near it; " and paſſing ſucceſſively over all the Stars of the *little Bear*, " did not efface the ſmaller ones in the Tail, which are of the " fifth Magnitude; ſuch was the extream Rariety, and Perſpi- " cuity of the Matter whereof it conſiſted.

" This ſingle Beam was very remarkable for its Height above " all thoſe, that, for a great while before, had preceeded it, " or that followed it.

" It being now paſt eleven of the Clock, and nothing new of- " fering itſelf to our View, but repeated *Phaſes* of the ſame " Spectacle; I obſerved, that the two *Laminæ*, or Streaks, " parallel to the *Horizon*, had now wholly diſappeared; and " the whole Spectacle reduced itſelf to the Reſemblance of a very

" bright

it) is generally terminated with a very lucid Arch, from one to four or five Degrees broad, whoſe Center is below the Horizon. Sometimes

" bright *Crepuſculum* ſetting on the Northern *Horizon*, ſo as to " be brighteſt and higheſt under the Pole itſelf; from whence it " ſpread both Ways into the North-eaſt and North-weſt. Un- " der this, in the Middle thereof, there appeared a very black " Space, as it were the Segment of a leſſer Circle of the Sphere " cut off by the *Horizon*. It ſeemed to the Eye like a dark " Cloud, but was not ſo; for by the Teleſcope the ſmall Stars " appeared through it more clearly than uſual, conſidering " how low they were: And upon this as a *Baſis*, our *Lumen* " *Auroriforme* reſted, which was no other than a Segment of a " Ring, or *Zone* of the Sphere, intercepted between two pa- " rallel leſſer Circles, cut off likewiſe by the *Horizon*; or the " Segment of a very broad *Iris*, but of one uniform Colour, " *viz.* a Flame-Colour inclining to Yellow, the Center thereof " being about forty Degrees below the *Horizon*. And above " this there were ſeen ſome Rudiments of a much larger Seg- " ment, with an Interval of Sky between, but this was ſo ex- " ceeding feint and uncertain, that I could make no proper " Eſtimate thereof.

" I attended this *Phænomenon* till near three in the Morning, " and the Riſing of the Moon: But for above two Hours toge- " ther it had no Manner of Change in its Appearance, nor Di- " minution, nor Increaſe of Light; only ſometimes, for very " ſhort Intervals, as if new Fewel had been caſt on a Fire, the " Light ſeemed to undulate and ſparkle not unlike the riſing of " a vaporous Smoak out of a great Blaze when agitated. But " one Thing I aſſured myſelf of, that the *Iris*-like Figure did by " no means owe its Origin to the Sun's Beams: For that about " three in the Morning, the Sun being in the Middle between " the North and Eaſt, our *Aurora* had not followed him, but " ended in that very Point where he then was: Whereas in the " true North, which the Sun had long paſſed, the Light re- " mained unchanged, and in its full Luſtre."

Appearances of this Kind have been taken Notice of both by *Pliny*, *Seneca*, and *Ariſtotle*; the laſt of which calls the vibrating Light near the *Zenith*, Δαλοί; the more ſteady perpendicular Streams, Δοκόι; and the *Aurora* itſelf, from the apparent dark Cloud juſt below it, Χάσμα. That *Aurora* which was obſerved by

times there are two or more of theſe Arches, one above another. In ſome, the Cloud is not terminated by an Arch, but by a long bright Streak

by Monſieur *Gaſſendi* in *Provence*, on the 21ſt of *September*, in the Year 1621, was very remarkable, at that Time.

He tell us, that about the End of Twilight in the Evening, when the Sky was very clear, and there was no Moon, there appeared in the North a Sort of a riſing Morn, which aſcending by Degrees, became intermingled with certain Streaks, as it were, or Rays perpendicular to the Horizon: And that at the ſame Time there appeared ſome ſmall *paſſing* whitiſh Clouds between the South and the Place of the Sun's ſetting in Winter: and that in the Place where the Sun ſets in Summer, a bright Redneſs ſeemed to ariſe in the Form of a *Pyramid*, which moved towards the ſetting of the Sun at the *Equinox*; and which was diſtinguiſhed into three ſeveral *Pyramids*, which in a little Time were confounded one with another, and at laſt diſappeared. When this Redneſs ceaſed, the northen Whiteneſs was riſen forty Degrees and more, that is, about the Altitude of the Pole-Star, forming itſelf into an Arch, and taking up near ſixty Degrees of the *Horizon*. After this, certain *Chevrons*, or Columns of Rays, ſome whiter, and ſome a little darker, began more plainly to be diſtinguiſhed, of about two Degrees in Breadth, and perpendicularly poſited; ſo that all that Part appeared as it were fluted. The whole Circumference immediately appeared ſcalloped; and then ſome of thoſe Columns which were in the Middle, and that were the whiteſt, began as it were to leave their Places with great Impetuoſity, and in leſs than a Quarter of a Minute, raiſed themſelves almoſt to the Top, putting on the Form of *Pyramids*, which they would retain four or five Minutes. It was about nine of the Clock, when the Arch of Whiteneſs began to decreaſe or ſink; at which Time certain very white Streams of Smoke began to iſſue out from the Columns which were remaining under the *Pyramids*, and darting upwards with very great Rapidity through the *Pyramids*, like Javelins, vaniſhed immediately when they came to the Tops of them. This Spectacle laſted about an Hour; after which the Whiteneſs ſunk down to about ſix Degrees of the *Horizon*. *Vide Abregé de Gaſſendi*, Tom. V. P. 245.

This

Streak of Light, lying parallel to the *Horizon*. The Limb of this luminous Arch, or parallel Streak is not always even and regular, but ſinks lower in ſome Parts, than in others.

3. Out of this Arch proceed Streams of Light, generally perpendicular to the *Horizon*, but ſometimes a little inclined to it. Moſt of them ſeem to end in a Point, like *Pyramids* or *Cones*; and often very much reſemble the Tails of *Comets*. Sometimes there is no luminous Arch, nor Streak of Light; and then the Streams ſeem to iſſue out from behind the dark Cloud, being diſtinct from each other at their *Baſes*.

4. The upper Ends of the Streams inceſſantly appear and vaniſh again, as quick as if a Curtain were drawn backwards and forwards before them; which ſometimes cauſes ſuch a ſeeming trembling in the Air, that you would

This *Phænomenon* appeared not only to *Gaſſendi* in *Provence*, but was ſeen at Places very diſtant from thence, as *Toloſe*, *Montaubon*, *Bourdeaux*, *Grenoble*, *Dijon*, *Paris*, and *Roan*, &c. and at moſt other Places in *France*, and the neighbouring Countries, that lie to the Northwards of *Provence*, unleſs where it was intercepted by Clouds; but no where in ſuch as lie at any great Diſtance to the Southwards of it.

Monſieur *Gaſſendi* is thought to have given the Name of *Aurora Borealis* to this *Phænomenon*; but this is obſerved by Monſieur *Mairan*, to be a Miſtake. See Mr. *Mairan*'s Phyſical and Hiſtorical Treatiſe of the *Aurora Borealis*, in the *Memoires de l' Academie Royale des Sciences*, *Année* 1731. or an Abſtract of it in Philoſoph. Tranſact- N°. 431.

imagine the upper Part of the Heavens to be, as it were, in Convulſions *.

5. They ſometimes ſeem to meet in the *Zenith*, or more commonly to the Southward of it, about ten Degrees, more or leſs (ſometimes they deviate a little to the South-eaſt of the *Meridian*, and ſometimes to the South-weſt); and there curling round, in ſome Meaſure, imitate Flame confined under an Arch; and being frequently tinged with various Orders of Colours, exhibit a moſt beautiful Appearance, reſembling a Canopy finely painted †, of about ten or twenty Degrees in Breadth.

In many *Aurora*'s, there are Streams aſcending from thoſe Parts of the Heavens, which lie ſeveral Degrees to the Southwards of the Canopy; and in ſome, they appear to ariſe, though very rarely, almoſt as large, and numerous from the ſouthern, as from the northern Parts of the Horizon.

6. The Height of the *Aurora Borealis* is very great; for that of *March* the ſixth $17\frac{1}{16}$ was viſible from the Weſt Side of *Ireland*, to the Confines of *Ruſſia* and *Poland* on the Eaſt, and perhaps farther; extending at leaſt over thirty Degrees of Longitude, and in La-

* See their Motions well deſcribed in the Account we have of an *Aurora* in the Philoſoph. Tranſact. N°. 395. Art. 2.

† See the various Colours of the Canopy, as well as thoſe of an *Aurora* itſelf, accurately deſcribed by Pr. *Greenwood*, in Philoſoph. Tranſact. N°. 418. Art. 1.

titude

titude from about the fiftieth Degree over almoſt all the North of *Europe*, and at all Places, exhibiting, nearly at the ſame Time, the ſame Appearances.

7. Theſe Appearances have always been very frequent (as far as the Accounts we have of them inform us) in Countries that lie in, or near the *frigid Zone*, but very rare in thoſe of our Latitude; they are now become very frequent with us, but always ſeem to proceed from the North; and are as yet unknown to the Inhabitants of the more ſouthern Parts of our *Hemiſphere*. Whether they are ſeen to thoſe, who inhabit in, or near the other *frigid Zone*, is to us unknown.

8. In ſome, there are Trains of Light running horizontally, ſometimes from the Middle to the Extremes, and ſometimes from one Extreme to the other. And from theſe Trains often ariſe Streams perpendicular to the *Horizon*, and accompanying them as they paſs along.

9. When all the Streaming is over, the *Aurora Borealis* commonly degenerates into a bright Twilight in the North, and there gradually dies away.

10. It is probable, that theſe *Phænomena* often happen in cloudy Nights, though we are not ſenſible of them; for 'tis obſervable, that in ſuch Nights, there is frequently more Light

than what uſually proceeds from the Stars alone.

The moſt obvious Solution of the *Aurora Borealis*, or at leaſt what would appear ſo, to ſuch as have only attended to the Circumſtances of ſome particular ones, and which has accordingly been affixed by ſeveral * to their Accounts of the *Aurora*'s they have ſeen, is that it is a thin Nitro-ſulphureous Vapour, raiſed in our Atmoſphere conſiderably higher than the Clouds; that this Vapour by Fermentation takes Fire, and the Exploſion of one Portion of it kindling the next, the Flaſhes ſucceed one another, till the whole Quantity of Vapour within their Reach is ſet on Fire.

* Profeſſor *Cotes*, at the End of his Deſcription of a *Phænomenon* of this Kind, inſerted in the Philoſophical Tranſactions N°. 365, obſerves, that ſuppoſing a Fund of Vapours or Exhalations at a conſiderable Height above us to be diffuſed every Way into a large and ſpacious Plane, parallel to the *Horizon*, that Fund of mixed Matter by Fermentation will emit Streams; and that if the Wind be ſtill, they will aſcend perpendicularly upwards; otherwiſe they will be inclined towards that Point of the Horizon which is oppoſite to that from which the Wind blows; and that they will appear, by the Rules of Perſpective, in the firſt Caſe, to converge to the Spectator's *Zenith*, in the other, to ſome Point not far from it; and that if this Fund of Vapours be ſituated more to the North than the South, it will produce Streams of Light attended with ſuch Circumſtances, as then appeared: But he does not ſay, why the Vapours ſhould be ſituated rather to the North than to the South, or proceed to account for all the *Phænomena* of the *Aurora Borealis* in general from thence.

Some

Some have thought, that Vapours rarefied exceedingly by ſubterraneous Fire, and tinged with ſulphureous Steams, might from thence be diſpoſed to ſhine in the Night, and riſing up to the Top of the Atmoſphere, or even beyond its Limits (as we find the Vapours of Gun-powder, when heated in *Vacuo*, will ſhine in the Dark, and aſcend to the Top of the Receiver, though exhauſted) might produce thoſe Undulations in the Air, which conſtitute this *Phænomena*.

But theſe *Hypotheſes* have been rejected, as inſufficient: it having been thought impoſſible to account for all the Circumſtances of the *Aurora* by them *.

* In the Commentaries of the Academy of Sciences at *Petersburgh*, I find a late Solution of the *Aurora Borealis* from Exhalations fermenting and taking Fire in the Atmoſphere, which the Author *Chr. Maier* ſays, occaſion the Appearance of the lucid Arch in the North, and thinks that the Streams, which ſeem to iſſue from thence, are no other than the Light of that Arch reflected to us from the under Side of ſome thin Clouds, that lie above it. As to its appearing in the North rather than in the South, he ſuppoſes that may be owing to the Cold of thoſe Regions condenſing the Exalations, and thereby rendering them more liable to ferment than they are in the ſouthern; but acknowledges ingenuouſly, that he has no Reaſon to ſuppoſe this, but its being neceſſary to his Solution. At the End he tells us, That it was known in ancient Times as well as lately: But omits taking Notice, that it appears much oftner of late Years in our Climate than it uſed to do; and ſo avoids accounting for that Particular. *Vide Commentar. Academ. Scientiar. Imperial. Petropolitan.* Tom. I. p. 351.

Dr.

Dr. *Halley* therefore has Recourſe to the *magnetic Effluvia* of the Earth, which he ſuppoſes to perform the ſame Kind of Circulation with Regard to it, as the *Effluvia* of any particular *Terrella* * do with reſpect to that, *viz.* that they enter the Earth near the South Pole, and pervading its Pores, paſs out again at the ſame Diſtance from the northern: And thinks, they may ſometimes, by the Concourſe of ſeveral Cauſes very rarely coincident, and to us as yet unknown, be capable of producing a ſmall Degree of Light, either from the greater Denſity of the Matter, or perhaps from the greater Velocity of its Motion; after the ſame Manner, as we ſee the *Effluvia* of *Electric* Bodies emit Light in the Dark.

Monſieur de *Mairan* has given us a Phyſical and Hiſtorical Treatiſe of the *Aurora Borealis*, and endeavours to prove that it is owing to the *Zodiacal Light*, or the Atmoſphere of the Sun, ſpread on each Side of it along the *Zodiac* in the form of a *Pyramid*. This, he ſays, is ſometimes extended to ſuch a Length as to reach beyond the Orbit of our Earth, and then mixing itſelf with our Atmoſphere, and being of an *Heterogenous* Nature, produces

* A round Magnet, ſo called from the Reſemblance it bears to the Earth.

the

the ſeveral Appearances, which are obſerved in the *Aurora Borealis* *.

I have juſt mentioned theſe two Solutions, becauſe they come from two very ingenious Philoſophers; though I doubt not but the Reader will agree with me, that they are much too fine ſpun to hold, and that they are no other than the ingenious *Reveries* of Perſons determined to frame an Hypotheſis at any Rate. I queſtion not, but we may find Materials for the *Aurora Borealis*, without going ſo far for them, as theſe Gentlemen have done; and in particular that we have no Occaſion to have Recourſe either to the *magnetic Effluvia* of the Earth, or the *Zodiacal* Light, the Nature of both which we are wholly unacquainted with. The Materials employed in the firſt Solution (I mean ſuch *Effluvia* as are continually exhaled from the Surface and Bowels of the Earth) if rightly conſidered, will afford a very eaſy and natural one, as I ſhall endeavour to ſhew in the following Manner.

Firſt, we are aſſured by Experiment, that there are ſome Steams (as inflammable ſulphureous ones) which are capable of ſo great a Degree of Expanſion, that they will render themſelves lighter than the Air they float in, though

* See his Account at large, referred to at the End of Note, Page 155.

it

it be as rare, as it can be made by Art; for they will riſe to the Top of the Receiver, when exhauſted *, that is when as much Air, as is poſſible, is drawn out †: Such Steams therefore or Exhalations, riſing out of the Earth from Mines, Vulcano's, &c. muſt neceſſarily be buoyed up towards the Top of the Atmoſphere, at leaſt, till they come to a Region, where the Air is as rare and expanded, as it can be made by the *Air Pump*, here below. This Height according to Dr. *Halley*'s Computation §, (which he founded upon the Air's Elaſticity) is about forty or fifty Miles: but probably it is much greater; for the Air, which is higher than Vapours and other *Heterogeneous* Matter that is not elaſtic, riſe to, being much purer than any we can make Experiments upon, may be indued with a much greater Degree of Elaſticity, and ſo the Atmoſphere may be conſiderably higher, than what he upon that Principle, computes it to be.

Secondly, Theſe *Effluvia* being raiſed to the Top of the Atmoſphere, or near it, and floating there, will neceſſarily be carried towards the polar Parts thereof, for the following Reaſons. 1. Becauſe the ſuperior Current

* See Philoſoph. Tranſact. N°. 347 and 360.

† It is impoſſible to extract all the Air out of a Veſſel, becauſe it is by the Spring of the Air remaining in the Veſſel, that the Valves of the Pump are opened at each Stroke.

§ Philoſoph. Tranſact. N°. 181.

of

of the Air, to a great Diſtance from the *Equator*, is that Way *. 2. We know from Experiment, that whatever ſwims upon a Fluid which revolves upon an *Axis*, is thereby carried towards that *Axis*. This is exactly the Caſe of theſe *Effluvia*, for they ſwim near the Top of the Atmoſphere which continually revolves about the *Axis* of the Earth; they muſt therefore neceſſarily be carried towards the polar Parts thereof.

Thirdly, Theſe *Effluvia* being collected together at, or near the Poles, and of an inflammable Nature, may eaſily be ſuppoſed to ferment, when they meet with other *heterogeneous* ones proper to produce ſuch an Effect, and emit Streams of Fire; which Streams will naturally riſe up into ſuch Parts of the Atmoſphere as are ſtill lighter than that wherein the *Effluvia* reſt, that is, directly upwards from the Center of the Earth. But, according to the Rules of *Perſpective*, thoſe Streams, though they really diverge, as *Radii* from a Center, will appear to a Spectator on the Surface of the Earth to converge towards a Point: which Point will ſeem to be directly over his Head, if the Streams aſcend in right Lines from the Center of the Earth: but if they deviate all one Way from that Direction, the Point will be on

* As explained in Diſſertation V.

that Side the *Zenith* towards which they incline *.

To illuſtrate this; ſuppoſe ſeveral Strings hung down from the Ceiling of a Room, and a Candle placed upon a Table below them, the Shadows of them all will converge towards the Point, that is over the Candle. And, if they are made to incline, ſuppoſe all one Way, the Point of Convergency will remove from over the Candle, towards that Side of the Room to which the upper Ends of the Strings incline: Now if a Perſon had viewed them from the Place where the Candle was, and referred their Places to the Ceiling, they would have ſeemed to him to have converged towards the Point, where the Shadows did.

And if the Streams ſpread themſelves as they ariſe, but not too much, they will nevertheleſs appear tapering towards the upper Ends, like *Cones* or *Pyramids*; juſt as the Sides of a long Walk ſeem to a Perſon that views them

* This may be made to appear in the following Manner; Let ADB (*Fig.* 38.) repreſent the *Concave* of the Heavens, AB the *Horizon*, C the Place of the Spectator, TV a luminous Subſtance ſending forth the parallel Streams EG, LM, NO, *&c.* Theſe Streams will all ſeem to converge towards the Point D, if that Point be taken ſuch, that the Line DC drawn from thence to the Spectator's Eye, be parallel to the Streams. For Inſtance, the Stream EG will ſeem to riſe from *e* to *g*, LM from *l* to *m*, and FH from *f* to *h*, and ſo of the reſt. And NO will appear wholly in D, the Place to which the reſt ſeem to converge. And if the Streams are as large, or ſomewhat larger at the upper Ends, than at the lower, they will ſtill appear leſs there, thoſe Ends being fartheſt from the Spectator's Eye.

from

from one End of it, or from a diſtant Place, to approach each other at that which is fartheſt from him.

This being premiſed, we may now account for the ſeveral *Phænomena* of the *Aurora Borealis* before laid down. As,

1. The Blackneſs of the Sky, which generally appears in the northern Parts of the *Horizon*, like a dark Cloud, is occaſioned by the Brightneſs of the luminous Matter of the *Aurora* juſt above it. That the Sky is clear here, is evident (as was obſerved before) becauſe the ſmalleſt Stars are ſeen through it.

2. The lucid Arch immediately above, is the luminous Matter of the *Aurora* itſelf, which ſometimes exhibits the Appearance of a Curve, ſometimes of a ſtrait Line, according to its Form and Situation in the Atmoſphere, though generally that of a Curve: For, by the Rules of *Perſpective*, when a ſtrait Line is diſtended horizontally, and above the Spectator's Eye, it ought to appear bent into a Curve, whoſe Center is below the *Horizon* *. Sometimes it appears on one Side the North Point, more

* Thus, when a Perſon ſtands fronting a Row of Houſes, and looks over the Tops of them, if they are all of an equal Height, that Houſe which is neareſt him, will ſeem to cut the Heavens in a Point that will be higher than where it is cut by any of the reſt; and the Points where the Heavens will ſeem to be cut by the Tops of thoſe, which are on the Right and Left Hand of the Spectator, will deſcend lower and lower, as the Houſes are farther off; ſo that the Points, taken all together, will repreſent a Curve.

than on the other; ſometimes regular, ſometimes irregular, as the various Circumſtances of the Air's Motion at the Top of the Atmoſphere, and of the Situation of the flaming Matter may be.

3. The Streams of Light, iſſuing out of the lucid Arch, are Streams of Fire emitted upwards from the Matter of the *Aurora*, and ſeem, for the Reaſons already laid down, to converge towards the *Zenith* of the Spectator. Why they incline a little ſometimes from the Perpendicular, will be explained in the fifth Remark, where we account for the Situation of the Canopy. When no luminous Arch appears, it is probable, that it is intercepted by the *Horizon*, or by the Vapours which float in great Quantities therein.

4. The trembling obſerved in the upper Part of the Heavens, is owing to the Quickneſs wherewith the Flaſhes ſucced one another, and alſo to the irregular Motions and Agitations of the ſuperior Parts of the Atmoſphere.

5. So long as the luminous Matter of the *Aurora* is all of it towards the North of us, the Streams cannot ſeem to meet in a Point at the Top, as will appear to any one that conſiders the Figure referred to in the Note (p. 164), but after it has advanced forwards, or become kindled over our Heads, then they appear to meet, and form the Canopy already deſcribed; and when it has paſſed further ſtill, they ſeem

to

to ariſe from all Parts; though they are much fainter on the ſouthern than on the northern Side, ſo long as the main Body of the *Aurora* remains on the northern Side of the Canopy, which it rarely, if ever, paſſes. The Reaſon why the Center of the Canopy is generally a few Degrees to the South of the Spectator's *Zenith* *, is becauſe the luminous Streams, which iſſue forth from the extreme Parts of the Subſtance of the *Aurora*, will naturally diverge a little from the middle ones; and, as thoſe which appear to us, proceed chiefly from the ſouthern Side (that being neareſt to us) the Point of Convergency will neceſſarily be placed to the South of our *Zenith*, according to what was ſaid above about the Inclination of the Strings hanging from the Ceiling of a Room. If the Center of the Canopy is ſometimes to the Eaſtward, and ſometimes to the Weſtward of the Meridian, that depends upon the Motion of that Part of the Air, which is above the Subſtance of the *Aurora*, and through which the Streams paſs, as they riſe. This alſo it is that makes the Streams ſeem to ariſe ſometimes a little obliquely.

* According to this Theory, the Center of the Canopy will always be near the Spectator's *Zenith*, where-ever he is; which I believe is the Caſe, for I have met with no Account where it is otherwiſe; and ſo every Spectator ſees a different Canopy, juſt as when ſeveral Perſons are viewing a Rainbow, no two Perſons ſee the ſame Rainbow at the ſame Time. See Part III. p. 208.

6. The

6. The great Height of the *Aurora* is owing to the exceeding Lightneſs of the *Effluvia*, which compoſe the Subſtance of it (as explained above) and the darting of the Streams upwards, into Regions perhaps quite above the Atmoſphere, occaſions it to exhibit at very diſtant Places the ſame Appearances at the ſame Time.

7. That the *Aurora* appears near the *Pole*, and never at or near the *Equator*, is becauſe of the Tendency the Matter of it has towards the Poles, as explained above. And that it appears in Places more diſtant from the *Pole*, than it formerly did, is becauſe the *Effluvia*, which are now raiſed from the Earth, are prevented from approaching ſo near the polar Parts of the Atmoſphere, as they uſed to do; thoſe Parts being already ſtocked with others, which were formerly raiſed, and are now grown *effete* by frequent Fermentations and Exploſions.

8. The *horizontal* Trains of Light are the Subſtance of the *Aurora* juſt taking Fire, which runs from one Part to another, as in a Train of Gun-powder kindled in any one Part; and ſends up Streams perpendicularly from Places, where it meets with a greater Quantity of Matter than ordinary.

9. When the Matter of the *Aurora* is ſo far ſpent, as to emit no more Streams, it appears only as a bright ſteady Light in the North, which

which gradually dies away, for Want of freſh Fewel to ſupport it.

10. As the Vapours, of which Clouds are formed, never riſe ſo high, as where the Matter of the *Aurora Borealis* floats; it is not at all inconſiſtent with the foregoing Theory, if it is ſometimes intercepted from our Sight, by the Interpoſition of Clouds below.

See farther on this Subject, *Ariſtotel.* Meteor. Lib. I. Cap. 4, 5. *Plinii* Hiſtor. Natural. Cap. 26, 27. *Senec.* Quæſt. Natural. Lib. I. *Lycoſt.* Prodigiorum ac Oſtentorum Chronicon, paſſim. *Julius Obſequens* de Prodigiis, Cap. 13, 43, 88. *Gaſſendi* Animadverſ. in *Diog. Laert.* Lib. X. p. 1157. *Cornelius Gemma* de divinis Naturæ Characteriſmis. *Nicephori* Hiſtor. Eccleſiaſt. Lib. XII. Cap. 37. *Iſid. Hiſpal.* Hiſtor. Goth. Tom. I. p. 65. Bibliothec. Orientalis Clementino-Vaticana, Tom. I. p. 407. *Gregor. Tur.* paſſim. Mem. de Lit. de l'Acad. des Inſcriptions & Belles Lettres, Tom. IV. p. 431. Miſcellan. *Berolin.* Tom. I. p. 137. Theatr. Comet. *Staniſ. Lubienietz*, p. 264, 348. Mem. pour ſervir â l'Hiſtor. de *France*, Tom. I. p. 168. Mem. de l'Acad. Royal de Sciences, for almoſt each Year ſince 1716. Philoſoph. Tranſ. N°. 305, 310, 320, 347, 348, 349, 351, 352, 363, 365, 368, 376, 385, 395, 398, 399, 402, 410, 418, 431; and the Authors referred to by Mr. *Johnſon*, in his Quæſt. Philoſoph. Cap. IV. §. 3.

DISSERTATION VIII.

Of Fermentation.

HAving had Occaſion to mention ſome of the Effects of Fermentation, it may not be amiſs, before I put an End to theſe Diſſertations, to add a ſhort Account of the Nature of it, and to ſhew how thoſe Effects are produced by it.

Fermentation is a mutual Commotion of the conſtituent Particles of Bodies, one among another; and ariſes from an Inequality in their Attractions of Coheſion. Authors diſtinguiſh it into two Kinds; the one is that which happens when a Solid is diſſolved by a Fluid; the other is, when two Fluids, being mixed together, ferment with each other.

Thoſe Authors, who have treated of the firſt of theſe, tell us, That to cauſe a Fermentation between a Solid and a Fluid, ſeveral Circumſtances are neceſſary. Particularly Dr. *Friend* *, and *Keil* †, are of Opinion,

1. That the Particles of the Solid muſt attract thoſe of the Fluid with a greater Force, than the Particles of the Fluid attract one another.

* See his Chymical Lectures.

† See his Letter to Dr. *Cockburn*, *De Legibus Attractionis.*

2. That

2. That the Pores of the Solid muſt not be too ſmall to admit the Particles of the Fluid into them.

3. That the Body be of ſo looſe a Contexture, that the Force of Impact, with which the Particles of the Fluid ruſh into its Pores, may be ſufficient to diſunite its Parts.

4. That the Elaſticity of the Particles tends very much to promote, and augment the Fermentation.

Dr. *Boerhaave* makes alſo four Conditions requiſite *.

1. That there be a due Proportion between the Size of the Particles of the Fluid, and the Pores of the Body to be diſſolved.

2. That the Figure of the Particles of the Fluid have a determinate Relation to that of the Pores of the Solid.

3. That the Particles of the Fluid be ſufficiently ſolid, that their Moment, or Force of Action may not be too weak.

4. The laſt Qualification, he mentions, is a fit Diſpoſition of the Particles of the Fluid, when received into the Pores of the Solid, to make ſome ſtay there, and not immediately to paſs through; but to act every Way upon the Solid, as they move towards the external Surface thereof.

* Dr. *Boerhaave*'s Chemiſtry, by *Shaw*, p. 344.

But we have no Occaſion to have Recourſe to ſo many Suppoſitions: if the Particles of the Solid attract thoſe of the Fluid with a greater Degree of Force than either thoſe of the Fluid, or thoſe of the Solid attract one another *, it is ſufficient; and there will follow a Diſſolution of the Body, as may clearly be demonſtrated from the Laws of *Mechanics*, whatever the other Circumſtances relating to the Figure or Magnitude of Pores, &c. may be †.

When

* This may be thought an impoſſible Suppoſition, for the Force of Attraction of Coheſion being as the Surfaces of the attracting Particles, whatever Size or Form the Particles of the Solid and Fluid are of, there cannot be a greater Quantity of Surface between every two Particles, one of which is a Particle of the Solid, and the other a Particle of the Fluid, than there is between every two Particles, which are either both of the Solid, or both of the Fluid; and therefore the Particles of the Solid cannot attract thoſe of the Fluid with greater Force than either thoſe of the Solid or thoſe of the Fluid attract one another. But it is to be conſidered, that we are not ſo well acquainted with the Nature of the Attraction of Coheſion, as to determine *exactly* in what Manner, and by what Laws it acts. The Experiments made Uſe of for this Purpoſe, only ſhew that ſo long as we try them with the ſame Kind of Bodies, the Attraction is larger where the Contact is ſo. See Part I. Chap. III. But we have no Method of determining, whether the Difference of Attraction, which *various* Bodies exert upon one another, ariſes ſolely from a Difference in their Surfaces, or not.

† *Dem.* Thus, let *f, f, f*, &c. (*Fig.* 39.) repreſent a Series of the Particles of a Fluid, and *s, s, s*, &c. a Series of thoſe of a ſolid Body, contiguous to one another: and let the pricked Lines *f f, f f*, &c. repreſent the Forces of Attraction between the Fluid Particles one among another, and *s s, s s*, &c. thoſe of the ſolid ones among themſelves; and let the black Lines *fs, sf*, &c. expreſs thoſe which are between the fluid and ſolid Particles. Now, the latter Forces being by the Suppoſition ſtronger thrn the former, the fluid Particles will recede from

When a Solid is put into a Fluid, if their Particles have the above-mentioned Relation to each other, thoſe of the Solid, being attracted with greater Force towards the Fluid, than they are the contrary Way, they will fall off from the Solid, and enter in between the Particles of the Fluid; and for the like Reaſon, thoſe of the Fluid will open to themſelves a Way in between thoſe of the Solid, and will ſeparate them from each other. Neither will their Reſpective Motions ceaſe, unleſs their

from each other, and ſuffer thoſe of the Solid to enter in between them; and for the ſame Reaſon the ſolid Particles will give Way to thoſe of the Fluid. By which means, the Diſtances repreſented by the pricked Lines becoming greater, the Attractions, which they expreſs, will be diminiſhed; ſo that the fluid Particles will enter quite in between the ſolid ones, and the ſolid ones between the fluid ones; and both of them together will conſtitute ſuch a Series, as is repreſented in *Figure* 40, in the middle Row *s*, *f*, *s*, *f*, *&c.* where the ſolid and fluid Particles lie mixed interchangeably one with another in a right Line. Now let it be ſuppoſed, that this Series is contiguous to one which conſiſts wholly of Fluid above it, as is expreſſed in the Figure, and to another below, conſiſting of ſolid Particles only. Every ſolid Particle in this Series will be attracted upwards with greater Force, than it is downwards; and every fluid one with greater Force downwards than it is upwards, as appears by bare Inſpection of the Figure, where the black Lines, as in the former, expreſs the ſtronger Attractions, and the pricked ones the weaker. And, if we ſuppoſe the Number of Particles in the Solid and in the Fluid to be nearly equal, thoſe of the Fluid will not ſtop, till they have quite paſſed through the Solid; for they will always find a Series wholly conſiſting of ſolid Particles before them, whilſt that which they leave behind, will be a Mixture of both. In like manner, the ſolid ones will paſs quite through the fluid ones; for they will always meet with more fluid ones before them, than they leave behind within the Sphere of their own Attraction.

Quantities be very unequal, till they are diffuſed uniformly one among another, as we may very eaſily conceive; for till then, there will always be ſome Particles attracted with a greater Degree of Force one Way than they are another.

And if more of the Solid be added to this Fluid, the Particles of the Fluid will alſo enter into that Solid, till each is ſurrounded on all Sides with ſolid Particles, as far as its attractive Force reaches. After which the Fluid will (as they ſay) be *ſaturated*, and will diſſolve no more.

Again, if more of the Fluid be poured upon that Solid, the ſolid Particles will diffuſe themſelves farther into the Fluid, till each of them is encompaſſed with Particles of the Fluid, as far as its attractive Force extends; and then they will ſpread themſelves no farther.

But in either Caſe, if another Solid, or Fluid, the attractive Force of whoſe Particles differ from thoſe of the former, be added, a freſh Fermentation will begin, provided the attractive Forces between the Particles of the former Mixture, and of thoſe which are now added, have ſuch a Relation to each other, as is neceſſary to produce it.

Upon this Principle it ſhould ſeem, that a Fluid ſhould always be capable of diſſolving more than an equal Quantity of a Solid; and that a Solid ſhould be capable of entering in and

and diffuſing itſelf through more than an equal Quantity of Fluid. The Reaſon why it is frequently not ſo, is becauſe it commonly happens, that the Fluid and the Solid are not of equal ſpecific Gravities. When the Solid is heavieſt, ſo many of its Particles will not aſcend and enter into the Fluid, as would otherwiſe have done; and on the contrary, when the Fluid is heavieſt, the Weight of its Particles will be an Impediment to their riſing into, and diſſolving ſo much of the Solid as it otherwiſe might have done.

We have no Occaſion to diſtinguiſh Fermentation into two Kinds, with regard to its Cauſes; for, according to the foregoing Theory, whenever two Fluids, or a Solid and a Fluid, are put together, if the Particles of the one attract thoſe of the other, with greater Force than either thoſe of the one, or thoſe of the other attract themſelves, a Fermentation will *equally* enſue, the Cauſe being the ſame in both Caſes.

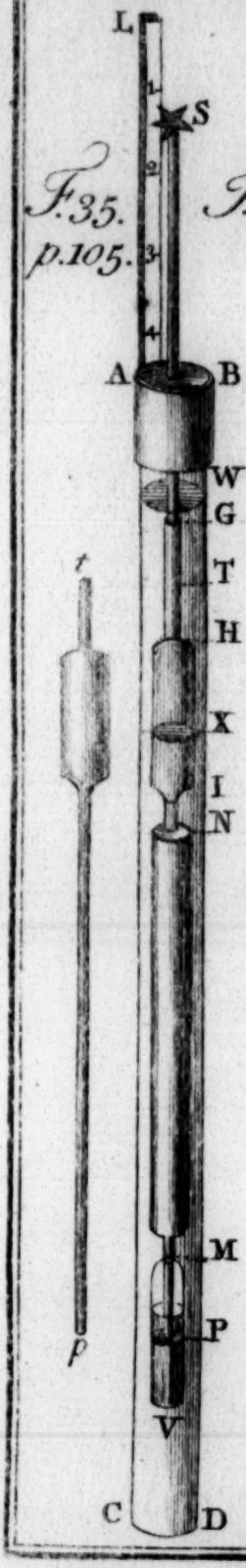
When two Fluids, or a Solid and a Fluid, ferment with each other, if the Agitation and *inteſtine* Motion of their Particles be very great, or continues a long Time, and if the Subſtance of them be of the inflammable Kind, they will, by continually rubbing one againſt another, be ſufficiently heated to take Fire, and burſt out into Flame; as was ſaid of the ſeveral Compoſitions mentioned in the foregoing Diſſertations.

See the Authors, who have explained and defended the old Solution, referred to by Mr. *Johnſon* in his Quæſtiones Philoſoph. Cap. III. Quæſt. 5, 6, 7.

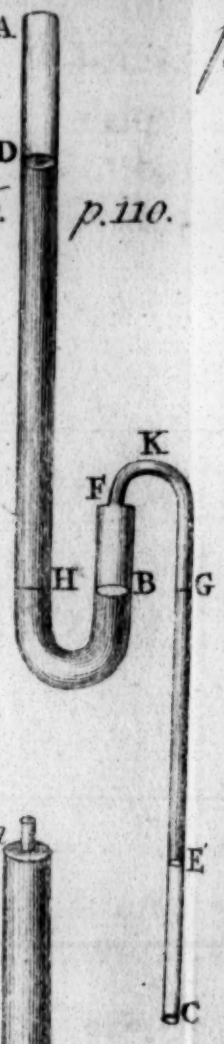
The End of the Second Part.

Part II. Plate VI. p. 176.

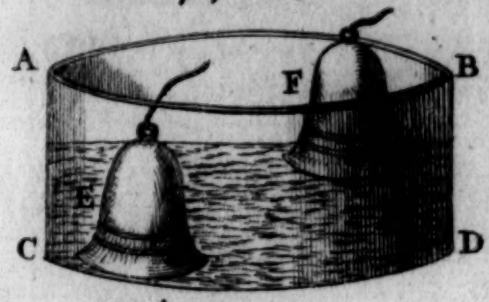
F. 35. p. 105.



F. 36. p. 110.

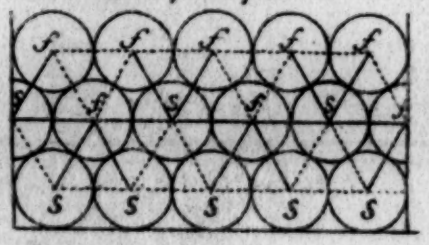


F. 37. p. 135.



F. 39. p. 172.

F. 40. p. 173.



F. 38. p. 164.